THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

Transportation and Tractors

TO mention now events that are scheduled for the last 2 months of the year may seem untimely, but during these months the Transportation and Service Meeting and the Tractor Meeting will be held at Boston and Chicago respectively. Excellent programs for these meetings have already been arranged, and the details will be announced in due course through the medium of THE JOURNAL and the MEETINGS BULLETIN.

Sections on the Job

FOREHANDEDNESS in the management of Sections affairs almost invariably spells success. On the contrary, the wait-till-the-last-minute procedure almost certainly promises failure.

The officers and committeemen of at least one of our Sections have already met, have selected through the medium of a questionnaire the general topics of greatest interest to the Section membership and have formulated a complete schedule for the year's activities. Speakers have been invited to address the various sessions, and in a number of cases acceptances have been received. That this Section will add to its record another year of splendid accomplishment is a safe assumption.

July Number in Two Sections

THIS issue of THE JOURNAL consists of two sections, Section 1 being the regular monthly issue for July and Section 2 the index to Vol. XVIII, that ordinarily would have been included in the June issue. This departure from the usual practice was made to enable the June issue containing the account of the Summer Meeting at French Lick Springs, Ind., on the first 4 days of last month to be mailed to the members on June 10.

If through an oversight you did not receive your copy of the semi-annual index, please write the Publication Department at the Society's headquarters in New York City. Comments from the members regarding this change in the manner of issuing the semi-annual index will be appreciated.

Riding-Qualities Bibliography

RESEARCH on riding-qualities during the last year has been confined to investigating the relative merits of the value of the contact-type accelerometer in determining the shocks experienced in automobiles.

As part of the preliminary work on the riding-qualities investigation, a bibliography was prepared by the Research Department and presented to the Riding-Qualities Session of the 1925 Annual Meeting.

The articles listed in the section on Instruments have been briefly abstracted and are grouped in the following subdivisions: accelerometers, decelerometers, impact, integrator, miscellaneous, oscillation, photographic, profilometer, roll, torsion, and vibration.

Although this material has not been brought uptodate, it is believed that any person interested in instrumentation and its allied subjects will find this bibliography of value. Copies will be forwarded to members free of charge upon receipt of a request.

Cooperative Fuel-Research

AT a recent meeting of the Society's Research Committee, John O. Eisinger, of the powerplant section of the Bureau of Standards, presented an informal report of tests on engine starting. Work on this particular problem has been in progress for some time and results have been published in THE JOURNAL as various phases of the work have been satisfactorily completed. This report reveals the influence of cranking speed on starting. It is pointed out that the quantity of fuel required for starting is practically the same at either 150 or 200 r.p.m. for any given rate of fuel flow over the entire range covered in the tests. However, below a cranking speed of 150 r.p.m., the quantity of fuel required for any given rate of fuel flow is generally greater.

To study the influence of vaporization, some tests were made on a specially designed intake-manifold that had approximately three times the inside wall-surface for the same cross-sectional area as the conventional manifold. However, no appreciable improvement in starting was found. Further interesting results were presented that reveal the influence of turbulence, compression and atomization on the starting characteristics of an engine. The report is printed, substantially in full, on p. 3 of this issue of THE JOURNAL.

Aeronautics and Production in September

THIS year's Aeronautic Meeting in Philadelphia on Sept. 2 and 3 bids fair to eclipse past Aeronautic Meetings from the point of view of technical interest and social possibilities. The three technical sessions have

been designed with a view to their broad appeal to aeronautical enthusiasts; the banquet promises to be one of the most attractive social events of the year, and the inspection visit of the Naval Aircraft Factory will reveal a multitude of items of importance in the development of aviation.

With the National Air Races following the Society's popular meeting and with the Sesqui-Centennial Celebration in full swing, it should be difficult, if not impossible, for persons interested in air transportation to remain absent from Philadelphia during the 2 big days, Sept. 2 and 3.

Although production matters will be discussed to some extent at the Aeronautic Meeting, the Production Meeting in Chicago, Sept. 21 to 23, will offer a wonderful opportunity for the extensive consideration of many of the most important production problems of the automotive industry. A great amount of interest has already been expressed in the Production Meeting and in the Stag Carnival that will be the chief social attraction. Elsewhere in this issue of THE JOURNAL, further details concerning the Aeronautic Meeting and the Production Meeting will be found.

Write the Constitution Committee

AS indicated in recent issues of THE JOURNAL, the Constitution Committee now has in hand the matter of recommending what Constitutional amendment is advisable at this time, with reference particularly to various activities within the scope of the Society's work, motor-vehicle operation and maintenance, for example, being directly represented on the Council by specifically named officers.

The Constitution Committee would like to have all members who care to do so address communications to the Committee at the office of the Society, giving their views and specific suggestions as to the best manner of amending the Constitution in view of the discussion that has been published, particularly that beginning on p. 474 of the May issue of THE JOURNAL.

Past-President Manly, in mentioning that design and production, as well as research affecting them, have been tied in so intimately with the activities of the various commercial organizations in the automotive field that it has never seemed necessary to emphasize the interest of the Society in these divisions by specific designation of members of the Council to represent them, has expressed the opinion that, inasmuch as the operation of automotive vehicles in fleets is conducted by entirely separate organizations, and is a rapidly developing division of automotive engineering, it is fundamentally important that the best interests of these operating organizations be fully recognized and adequately advanced.

Operation and Maintenance Committee Named

A SESSION of members particularly interested in engineering motor-vehicle fleet operation was held last month. Among those participating in the conference were F. K. Glynn, chairman of the Metropolitan Section; C. H. Keel; Neil MacCoull; R. E. Plimpton, associate editor of *Bus Transportation;* G. A. Round; F. J. Scarr, supervisor of motor service of the Pennsylvania Railroad; C. B. Veal; Councilor J. F. Winchester; and Manager Burnett, of the Standards Department of the Society. This meeting was part of the more or less informal activity that is being maintained pending the organization of a general committee on motor-vehicle operation as mentioned at the last meeting of the Council.

Personnel for the Operation and Maintenance Committee of the Society has been named. Mr. Winchester will serve as chairman. B. V. Evans, of the Detroit Motorbus Co., has been named as vice-chairman. Others appointed to the Committee, in addition to Messrs. Glynn, Plimpton, Scarr, Veal and Burnett, named above, are

D. L. Bacon, New York, New Haven & Hartford Railroad, New Haven, Conn.
Archibald Black, Garden City, N. Y.
F. P. Freeman, Public Service Transportation Corporation, Newark, N. J.
A. W. S. Herrington, City of Washington
F. D. Howell, Motor Transit Co., Los Angeles
W. P. Kennedy, Kennedy Engineering Corporation, New York City
F. Van Z. Lane, Equitable Coach Co., New York City
E. E. LaSchum, American Railway Express Co., New York City
J. W. Lord, Harrolds Motor Car Co., Long Island City, N. Y.
J. H. Lyons, City Transportation Co., Tacoma, Wash.
Major C. W. McClure, Motor Transport Corps, U. S. A.
John F. McMahon, Yellow Taxi Corporation, New York City
W. E. Martin, United Railways & Electric Co., Baltimore
L. H. Palmer, Fifth Avenue Coach Co., New York City
Winfred H. Roberts, Department of Plant and Structures of the City of New York
John Stilwell, Consolidated Gas Co., New York City

The matter of the Society giving operation and maintenance matters more specific, as well as systematic, attention came up at the December meeting of the Metropolitan Section. At a meeting of the special committee that recommended the organizing of the Operation and Maintenance Committee, Mr. Glynn stated that an examination of the Roster of the Society indicates that about 6 per cent of the members are engaged directly in fleet operation and maintenance. Naturally, there should be a definite arm of the Society charged with the duty of developing activities of interest to these members with relation to research, standardization and the presentation of papers and the holding of meetings. Progress in this field of endeavor is bound to be intense, as well as rapid and very extensive. The members of the special committee expressed the opinion that the Operation and Maintenance Committee should study the following topics particularly:

Uniform methods for testing oils and fuels
Garage design and equipment
Expected life of important vehicle-parts
Special maintenance and servicing tools, made by fleet operators as distinguished from equipment manufacturers
Dissemination of engineering data on and specifications of types and makes of motor-vehicle chassis
Nomenclature; definition of "operation," "inspection," "repairing," "overhauling," "reconditioning," and the like
Uniform system for comparing motor-vehicle performance and maintenance cost of fleet operation

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

ADDITIONAL ENGINE-STARTING TESTS

J. O. Eisinger Presents Informal Report at Semi-Annual Meeting Last Month

At the meeting of the Society's Research Committee which was held on June 2, at French Lick Springs, Ind., an informal report of the tests on engine starting was presented by John O. Eisinger. The report, substantially in full, is given here to indicate the progress of this work. In the near future this report will be elaborated and given together with other findings.

One of the present problems of the cooperative fuel research that is being conducted at the Bureau of Standards under the direction of a steering committee made up of representatives from the cooperating organizations: the American Petroleum Institute, the Bureau of Standards, the National Automobile Chamber of Commerce, and the Society of Automotive Engineers, is an investigation of engine starting. Work on this particular problem has been in progress for a little over 1 year and during that time two reports that contain the findings of this research work, have been presented to this Society.[1]

In the first report the test set-up and the experimental procedure were described. It will be recalled that in making these tests a four-cylinder truck engine is driven by a dynamometer at a constant speed, usually 100 r.p.m. With the engine turning over at a constant speed and therefore with a constant rate of air flow being delivered to the engine, different mixture-ratios can be obtained by manually changing the rate of fuel flow from the carbureter. A single jet mounted in place of the conventional carbureter is used to supply the fuel used for starting and changes in the rate of fuel flow are obtained by changing the head of gasoline on the jet. The time required to obtain an audible explosion is measured with a stop-watch. This is considered as the starting time and is observed for different rates of fuel flow. In presenting the results, these various rates of fuel flow are plotted against the corresponding times required for starting. This gives a graphical representation of the starting behavior of the engine for different mixture-ratios under the specific engine condition at which the test is made.

Influence of Engine Speed

One of the specific engine conditions that has not been touched upon to any extent in the previous reports, is that of engine speed. Consequently, tests were made to determine the influence of cranking speed upon starting and the results of these tests are shown in Fig. 1. Cranking speeds below 80 r.p.m. could not be obtained with the equipment at hand, therefore the speed range covered in these tests is not as comprehensive as that encountered under all service conditions, yet the tests are sufficient to give general indications as to what effect engine speed does have on starting. Such indications are what have been sought in this investigation rather than data as to the specific performance of a given engine at a given speed. It will be noticed that the quantity of fuel required for starting, which is obtained from the curves shown in Fig. 1 by multiplying the coordinates of the particular point in question, is practically the same for either 150 or 200 r.p.m., for any given rate of fuel flow over the entire range covered. However, below a cranking speed of 150 r.p.m. the quantity of fuel required for any given

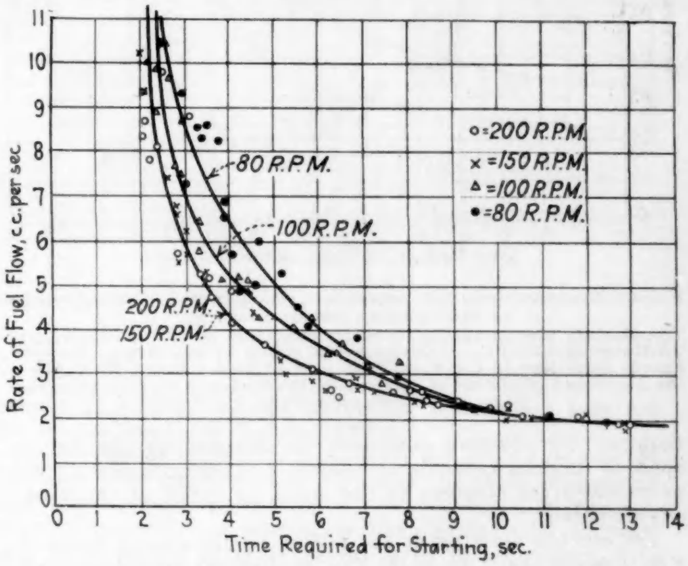


Fig. 1—Relation between Rate of Fuel Flow and Starting Time

The Results Shown Were Obtained with Commercial Gasoline at Cranking Speeds of 80, 100, 150, and 200 R. P. M. The Jacket-Water Temperature Was 7 Deg. Cent. (45 Deg. Fahr.) and That of the Intake Air Was 21 Deg. Cent. (70 Deg. Fahr.)

rate of fuel flow is generally greater. It must be remembered that the same rate of fuel flow for a cranking speed of 200 r.p.m. gives correspondingly richer mixtures as the cranking speed is decreased, due to the decrease in air flow, and when the results of the test shown in Fig. 1 are compared on a mixture-ratio basis the curves reproduced in Fig. 2 are obtained, whereas under these conditions the time

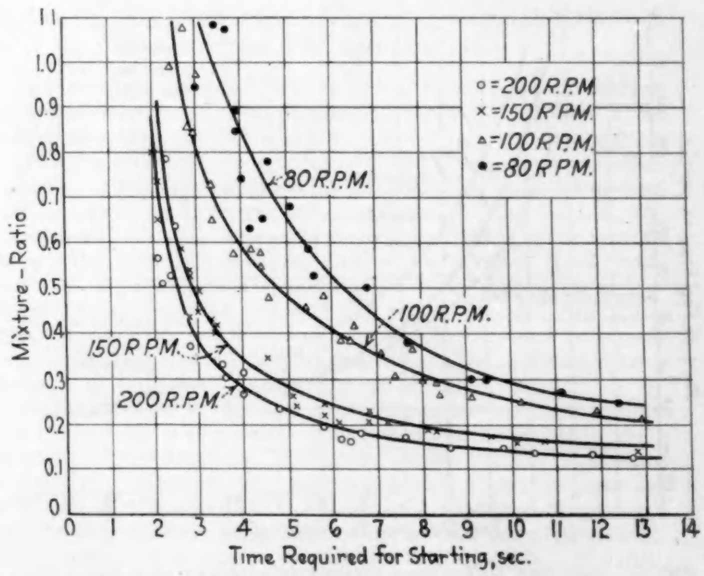


Fig. 2—Relation between Mixture-Ratio and Time Required for Starting

The Curves Shown Are Obtained by Comparing the Results of the Tests Shown in Fig. 1 on a Mixture-Ratio Basis. While the Time Required for Starting Continues To Decrease as the Engine Speed Is Increased, the Improvement in Starting Is Much More Pronounced for Changes in the Cranking Speed at the Lower Engine-Speeds

[1] See The Journal, July, 1925, p. 52; and February, 1926, p. 147.

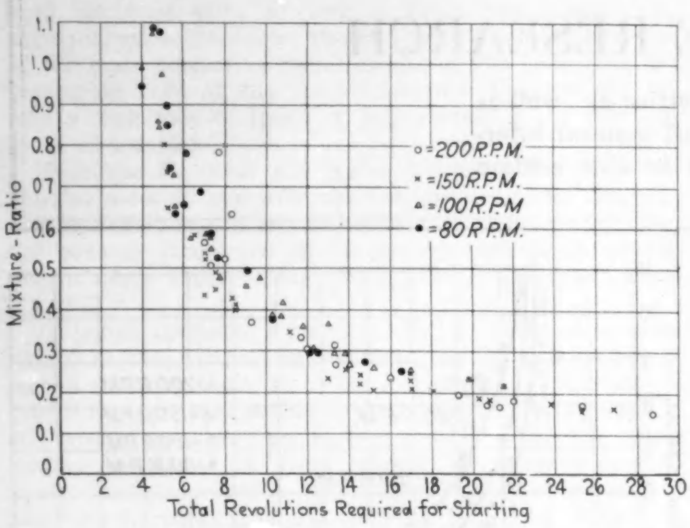


FIG. 3—RELATION BETWEEN MIXTURE-RATIO AND TOTAL REVOLUTIONS OF THE ENGINE BEFORE STARTING

The Results Shown in Fig. 2 Were Replotted on a Different Basis To Determine Whether the Quicker Starting at the Higher Engine-Speeds Was Due to the Fact That with a Higher Manifold Velocity the Necessary Richness of Mixture in the Cylinder Will Be Obtained in a Shorter Time

required for starting continues to decrease as the engine speed is increased, the improvement in starting is much more pronounced for changes in the cranking speed at the lower engine-speeds.

The quicker starting at the higher engine-speeds shown in Fig. 2 might result from the fact that at the higher manifold velocity the attainment of the necessary richness of mixture in the cylinder will be more rapid and therefore will require a shorter interval of time. To see if such were the case, Fig. 3 was plotted. This chart shows the total number of revolutions that the engine makes before starting. Under these conditions it will be noticed that within certain limits, for any given mixture-ratio the number of revolutions that the engine must make before starting is the same over the range of cranking speeds employed. With the low velocities that exist in the intake system at low engine-speeds, one would expect that a reduction in engine speed would increase the quantity of liquid that falls out of the charge before reaching the engine cylinder. Moreover, as the engine speed

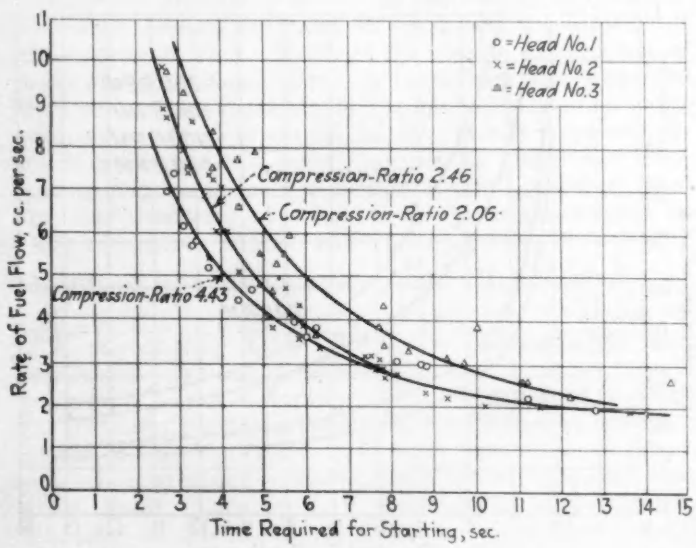


FIG. 4—HOW THE COMPRESSION-RATIO INFLUENCES THE TIME REQUIRED TO START AN ENGINE

In These Tests Commercial Gasoline Was Used as in the Others Reported on, but the Jacket-Water and Intake-Air Temperatures Were Different, Being 8 Deg. Cent. (46 Deg. Fahr.) and 23 Deg. Cent. (73 Deg. Fahr.) Respectively as Compared with 7 Deg. Cent. (45 Deg. Fahr.) and 21 Deg. Cent. (70 Deg. Fahr.). The Compression Pressures for the Three Heads Used Were 73, 29 and 21 Lb. per Sq. In.

is decreased the tendency for the compression to become isothermal rather than adiabatic increases. As both of these effects tend to increase the number of revolutions required for starting at low engine-speeds, the fact that experiments fail to show such an increase suggests the presence of some opposing influence, which very probably is the longer time available per revolution for vaporization.

In connection with vaporization some tests were made on a specially designed intake-manifold that had approximately three times the inside wall-surface for the same cross-sectional area as the conventional manifold. This increase in manifold wall-surface should promote more rapid vaporization in the manifold and consequently quicker starting, particularly at the lean mixture-ratios. No appreciable improvement in starting was found, however. This can probably be attributed to the fact that although the additional surface is undoubtedly beneficial from the standpoint of vaporization, before equilibrium conditions are established, it is likely to reduce the quantity of liquid gasoline that reaches the engine cylinder and that would otherwise become vaporized therein. Some rather crude experiments indicated that 1 cc. of the gasoline used would wet an area of about 50 sq. in. On that basis, the quantity of fuel that would be required to wet the additional surface furnished by the special manifold would be between 15 and 25 per cent of the total quantity required for starting.

HOW THE COMPRESSION-RATIO AFFECTS STARTING

The next factor that was investigated as influencing starting was the compression-ratio and the results of this phase are plotted in Fig. 4. That the improvement in starting at the higher compression-ratio is not due to the higher compression temperature seems probable in view of the fact that a reduction of between 35 and 40 per cent in the absolute temperature of compression when changing from heat No. 1 which had a compression pressure of 73 lb. per sq. in. gage to head No. 2 having a compression pressure of 29 lb. per sq. in. gage did not produce as marked an effect on starting as a change of approximately 6 per cent in the absolute temperature when changing from head No. 2 to head No. 3 which had a compression pressure of 21 lb. per sq. in. gage. The better operation at the higher compression-ratio is probably primarily due to the smaller clearance volume and the consequent decrease in the volume of the gases in the clearance space which mix with, and make leaner, the incoming charge. Incidentally some tests that were made on a head specially designed for turbulence and having the same compression-ratio as head No. 1 gave no improvement in starting. While the above mentioned experiments all indicate that an increase in compression-ratio is advantageous from the standpoint of starting, that considerably different results can be obtained with conditions producing serious leakage of charge by the pistons during starting is entirely possible. Such conditions are, however, obviously unsatisfactory.

Of particular interest are the experiments that have been made recently in connection with a study of atomization. In these tests a comparison of the starting of the engine is made between an ordinary jet, which is the one used in most of the previous work and which consists of a small tube ¼ in. in diameter with six equally spaced holes drilled radially near the closed end and an atomizing jet, for which an ordinary throat-spray was used. In this, air under slight pressure is passed through a small orifice in the center of which is located a small jet that was used in the tests to supply the fuel necessary for starting. Figs. 5 and 6 show the results obtained when using these jets. The fuel required for starting at either cold or room temperature is much less when using the atomizing jet. The discharge of fuel was vertical when using the atomizing jet and in the direction of the air flow, while that for the normal jet was perpendicular to the direction of air flow. Though this was by far the most convenient mounting for the atomizing jet, it was not at first considered permissible as earlier experiments had shown that with jets discharging vertically the starting time was affected by the location of the jet, presumably because this governed the vertical distance through which it was neces-

sary for the fuel to be lifted. Similar experiments with the atomizing jet, however, failed to show any such effect. In fact some experiments were made in which the jet discharged in the opposite direction to the air flow and even under such conditions it proved to be distinctly superior, as regards starting, to the normal jet.

Finely Atomized Fuel Gives Charge of More Uniform Quality

The quicker starting with the finely atomized fuel is probably due to a more complete diffusion of the fuel in the fuel-air mixture which thus produces a charge of more uniform quality. The following facts tend to show that this is the case. With the normal jet and approximately the leanest mixture that will fire, the first explosion is always very pronounced and the engine usually accelerates and continues to run for a considerable time after the fuel supply at the jet is turned off. With the atomizing jet, however, the sound of the explosion is extremely faint and the engine apparently does not fire after the fuel is turned off. At times the explosion is inaudible and is indicated only by a momentary marked increase in engine speed. With a uniform mixture, when the fuel-content of the charge at the spark-plug is just sufficient for the charge to be fired, the mixture throughout the cylinder is equally lean and one would expect the explosion to be very weak. If the mixture is not uniform, however, in order for the fuel-content of the charge at the spark-plug to be such that the charge can be fired, it may be necessary to have much richer mixtures elsewhere in the cylinder. Under such conditions the average fuel-content of the mixture required for ignition is higher than that of a charge of more uniform quality and the first explosion is correspondingly stronger.

Another group of measurements were made with a device that was a combination of primer and heater. In operation liquid was first deposited in a well at the bottom of the air horn and then heated by an electric coil for a certain length of time. While the device proved to be advantageous from the standpoint of starting, the efficiency of the device apparently was due to the time allowed for vaporization rather than to the heating action of the coil. The fact that apparently equally satisfactory results were obtained when the heating circuit was left open seems to warrant this conclusion. These comments should not be construed as implying that the heating is not beneficial but rather that the amount of heating in this particular installation was not sufficient to have any material effect.

[2] See The Journal, April, 1926, p. 393.

[3] See Bureau of Mines Technical Paper No. 323A.

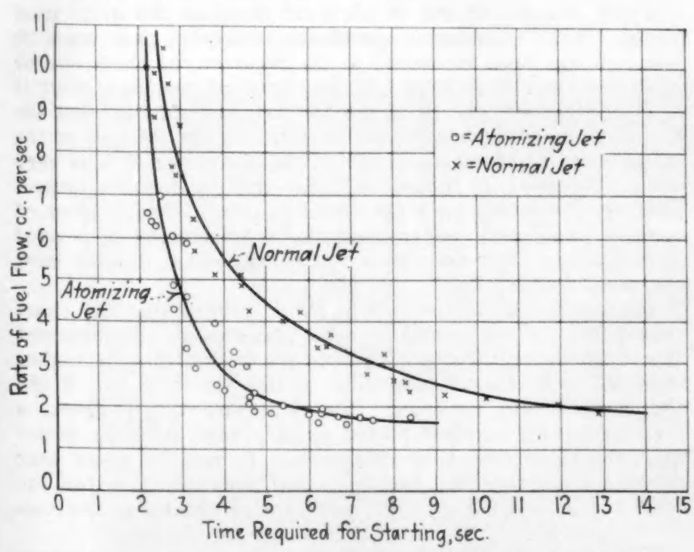


Fig. 5—Influence of Atomization upon the Time Required for Starting

The Atomizing Jet Discharged the Fuel Vertically and in the Direction of the Air Flow, while the Discharge from the Normal Jet Was Perpendicular. The Jacket-Water Temperature in These Tests Was 7 Deg. Cent. (45 Deg. Fahr.) and the Intake-Air Temperature Was 22 Deg. Cent. (72 Deg. Fahr.)

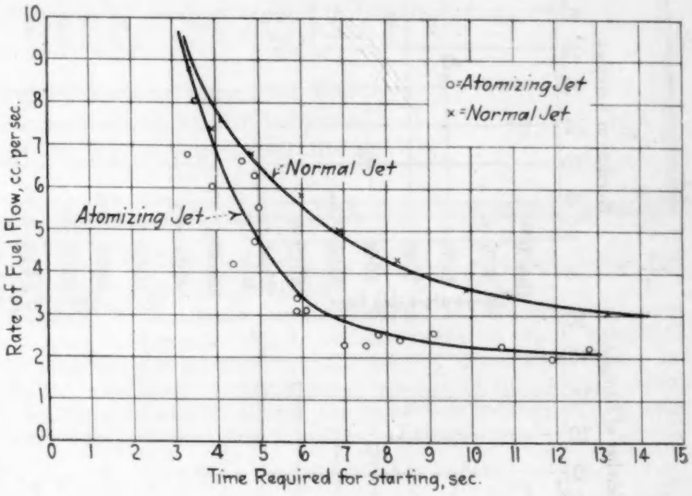


Fig. 6—Results Obtained in Another Series of Atomization Tests

In This Series of Tests the Jacket-Water and Intake-Air Temperatures Were Lower than in Those of Fig. 5, Being —7 Deg. Cent. (19 Deg. Fahr.) and 2 Deg. Cent. (36 Deg. Fahr.) Respectively

The foregoing discussion deals with the chief experiments that have been made in connection with the study of starting since the 1926 Annual Meeting of the Society. The Steering Committee recently recommended that starting tests be made with some special fuels to be prepared in accordance with specifications laid down by that Committee. These tests will be begun in the near future. Performance during the starting and "warming-up" period, particularly as regards acceleration, is also to receive attention and preliminary tests along these lines have already been made. Satisfactory progress has also been made in the development of laboratory methods for measuring fuel volatility and this is described to some extent in the paper presented by Mr. Sligh at the 1926 Annual Meeting of the Society entitled Progress in the Measurement of Motor-Fuel Volatility.[2]

GASOLINE VOLATILITY

Variation in Distillation Characteristics Determined from 138 Samples

Car builders are inclined to produce engines of higher compression-ratios. This tendency is based on the well-known fact that the thermal efficiency of internal-combustion engines increases if the compression-pressure is raised. The difficulty with high compression-pressures is that detonation and, in some cases, a general roughness of the engine, are encountered. It has been established that for a given engine design the different fuels as they are marketed throughout this Country may give very different results with regard to detonation. For this reason, the motor-car and truck industries have so far deemed it unwise to increase compression-pressures beyond a conservative value until they are assured of universal distribution of suitable fuel.

In response to a demand that originates perhaps mainly from motorists who object to the occasional knocking in their engines, non-detonating fuels are produced in increasing quantities. Gasoline for high-compression engines can be obtained in several ways. At present, mixtures of gasoline and benzol, as well as gasoline doped with tetra-ethyl lead, have become well known as non-detonating fuels. Further, cracked gasolines are gaining in favor because of desirable characteristics from the viewpoint of detonation.

The lack of uniformity in the characteristics of motor gasolines was recognized by the Government. Therefore, definite specifications[3] covering liquid fuels were drawn by the Government Specifications Board. Moreover, in the last 6 years the Bureau of Mines has conducted semi-annual

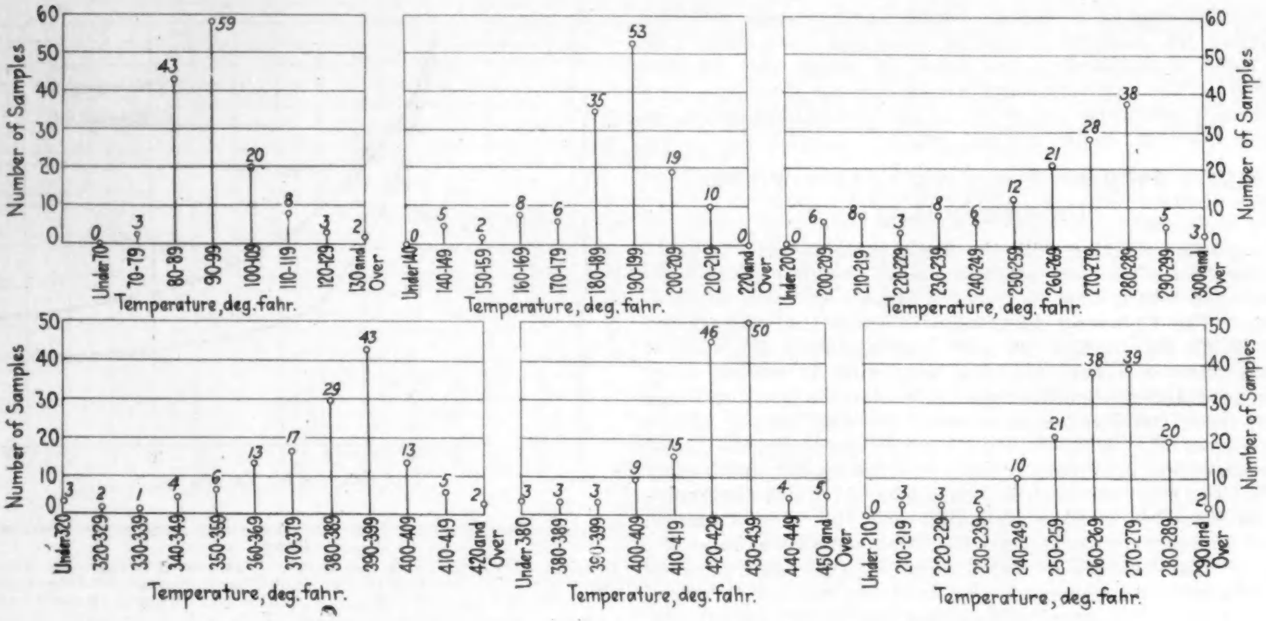


FIG. 7—VARIATIONS IN DISTILLATION CHARACTERISTICS OF 138 SAMPLES OF GASOLINE

These Samples Were Obtained in Connection with 13th Semi-Annual Motor-Gasoline Survey Conducted by the Bureau of Mines. From Left to Right the Charts in the Upper Row Represent the Initial Boiling, 20 and 50-Per Cent Points and Those in the Lower Row Give Similar Information in the Same Order, for the 90-Per Cent and End-Points and the Average of All the Samples. The Limits of the Federal Specification for the Various Points Are Given in the Following Table

Point	Initial-Boiling	20-Per Cent	50-Per Cent	90-Per Cent	End-Point
Temperature, deg. fahr.	131	221	284	392	437

surveys to determine the changes in the characteristics of motor gasoline. The samples tested periodically by that Bureau are secured in cities that represent the most important marketing territories of this Country.

While the distillation characteristics of a motor fuel are not a direct indication of a fuel's tendency to detonate when ignited, dependable statistical records pertaining to variations in distillation characteristics are of interest to both the petroleum and the automotive industries inasmuch as lack of uniformity is the main obstacle to a more universal use of higher compression-ratios.

R. J. Kennedy, of the Bureau of Standards, has taken some important figures from the 13th Semi-Annual Bureau of Mines Motor-Fuel Survey and plotted the curves that are reproduced in Fig. 7. These charts represent variations in distillation characteristics as obtained from 138 samples. Each of these, with the exception of the one in the lower right corner, represents the condition for a definite point of the distillation range, while the remaining one represents the mean volatility. In all cases the abscissas represent temperatures while the ordinates represent number of samples.

The chart at the upper left depicts the variation in the initial boiling-point for the 138 samples. It will be noted that for the 59 samples represented by the largest ordinate the initial boiling-point was found to be more than 90 deg. fahr. but less than 100 deg. fahr. The Government specifications previously referred to require that when the first drop falls from the end of the condenser the thermometer shall not read more than 131 deg. fahr. This chart reveals that only two samples for which the initial boiling-point was higher than 130 deg. fahr. were found. The other 136 samples showed initial boiling-point characteristics that were better than the minimum required in the Government specifications. This indicates that the gasolines are all very much better than the Government requirements with regard to starting-ability. This is due possibly in part to the fact that the semi-annual survey under consideration was conducted during cold weather when oil refineries habitually use a greater percentage of light constituents in the products that they market.

The chart in the center of the upper row shows the variations at the 20-per cent point of the distillation curve for the 138 samples. The Government specifications require that when 20 per cent has been recovered in the receiver the thermometer shall not read more than 221 deg. fahr. It will be noted from this chart that no samples were found that did not meet the Government specifications for the point under consideration. Therefore, the same remarks made with regard to the previous chart apply to this.

The variations at the 50-per cent point are illustrated at the upper right. The Government specifications require that when 50 per cent has been recovered in the receiver the thermometer shall not read more than 284 deg. fahr. This chart reveals that only eight samples did not come within the Government specifications. However, as the 50-per cent point is generally recognized as of little significance, this seems unimportant. It is interesting to note that at this point the variation in the various samples is very great.

The chart at the lower left represents the condition for the 138 samples at the 90-per cent point of the distillation range. The Government specifications require that when 90 per cent has been recovered in the receiver the thermometer shall not read more than 392 deg. fahr. From this chart it will be observed that 19 of the 138 samples did not meet the Government specifications at this point. As in the case of the 50-per cent point the variation in the characteristics is very wide. However, it should be noted that by far the largest number of samples meet the specified point. The number of samples that were better than the requirements is several times greater than the number of samples that did not meet the requirements.

The variation in the end-point is represented on chart reproduced in the center of the lower row. Government specifications require that the end-point shall not be higher than 437 deg. fahr. According to this chart, 9 out of the 138 samples did not meet this requirement. However, a preponderating number either exactly met or were better than the Government specifications. It will be noted that the variation for this point is much smaller than for the other test-points except that representing the initial boiling-point.

The chart at the lower right represents the average boiling-point or the mean volatility; a composite of all the other points. It may be repeated that the most important points are the 20-per cent point, with regard to starting ability, and the 90-per cent point which serves as an indication of volatility for complete vaporization.

MEETINGS OF THE SOCIETY

News accounts of National and Section meetings that were held during the preceding month, as well as announcements of forthcoming meetings, are presented in this department

ROHRBACH AT AERONAUTIC MEETING

Prominent Designer To Be Among Speakers at Philadelphia Gathering

Speaking on the topic, Economical and Rapid Production of Metal Airplanes and Seaplanes, Dr. Adolf Rohrbach of the Rohrbach Metall-Flugzeugbau, of Berlin, Germany, will provide one of the outstanding features of the big Aeronautic Meeting at the Bellevue-Stratford Hotel in Philadelphia, Sept. 2 and 3.

Other Important Topics

Airplanes for individual ownership will be discussed from several different angles by such persons as Elwood Junkin of "Waco," Edward Stinson of Stinson Sales Corporation, and A. V. Verville of the Buhl-Verville Aircraft Co.

At the session on engines the discussion will be concentrated largely on the development of air-cooled internal-combustion units for aircraft. Commander E. E. Wilson, U.S.N., who is in charge of the aircraft engine division of the Bureau of Aeronautics, will present a paper of very broad scope on the development of air-cooled engines for aircraft. Others who will cover the same topic from different specific angles will be G. J. Mead, of the Pratt & Whitney Aircraft Co., and E. T. Jones, of the Wright Aeronautical Corporation.

How I Fly at Night

One of the most popular sessions will be that devoted to air transport in which a paper on How I Fly at Night will be presented by W. L. Smith who is perhaps the best-known among the pilots of the Air Mail Service. Pilot Smith's presentation has been authorized by W. I. Glover, second assistant postmaster general, and in it the speaker will present an intimate picture of the problems involved in actual flying.

C. T. Ludington, of the B. B. T. Corporation of America, and H. C. Ritchie, of the General Electric Co., are collaborating on a paper that will cover methods and equipment for the illumination of air routes.

Lieut. L. M. Wolfe and Capt. W. H. Murphy will present an address in which will be revealed many practical considerations involved in the use of directional radio in flying. In view of recent developments in directional radio, this feature will be among the most noteworthy. These officers will represent the Army Air Service.

The Banquet and Visits

A real treat will be provided in the Aeronautic Banquet that will be held on the evening of Sept. 2. The Committee is not as yet prepared to divulge the identity of the principal speaker but offers assurance that he will present a great attraction.

Through Commander Wilson, arrangements have been made for providing a special exhibition of material and performance at the Naval Aircraft Factory. A half-day during the Aeronautic Meeting will be devoted to an inspection visit at this important naval station.

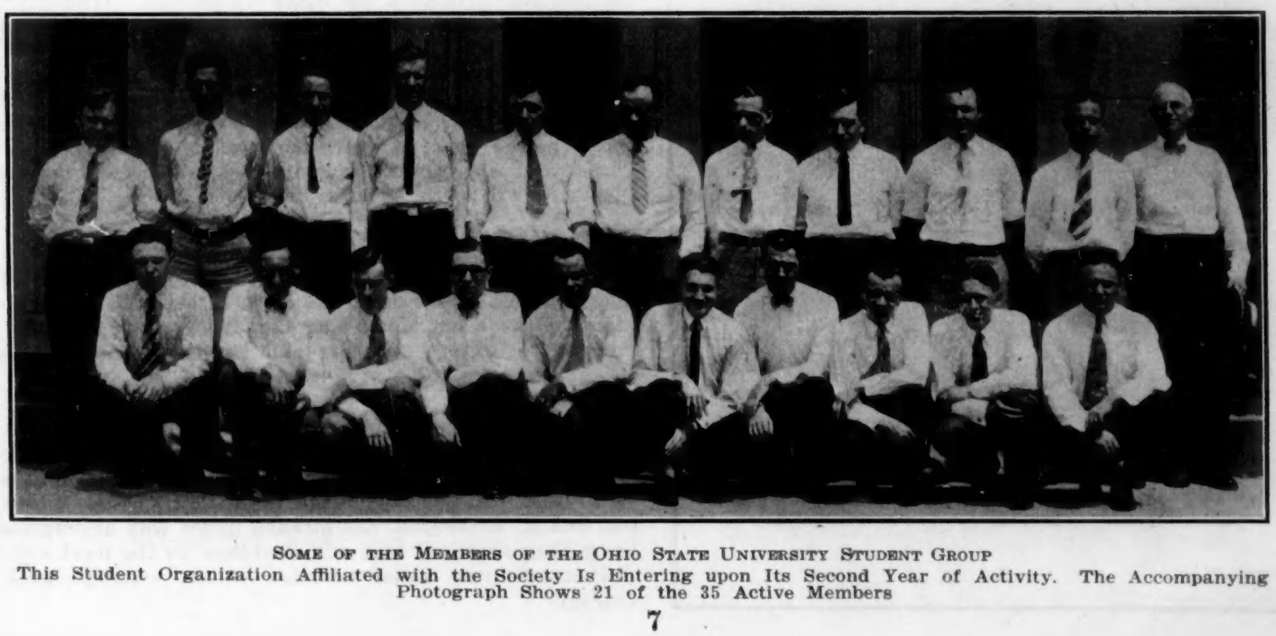
Many of those who attend the Aeronautic Meeting will wish to arrive in advance of the Meeting to enjoy seeing the Sesqui-Centennial Celebration. They will also find it pleasurable to remain after the close of the Meeting to witness the National Air Races that will occupy the days from Sept. 4 to 11 inclusive.

NEW STUDENT OFFICERS CHOSEN

Group at the Ohio State University Selects Active Workers

A photograph of 21 active members of the Ohio State University Student Group of our Society is reproduced on this page. During the last year this Group has been officered by the following: C. W. Smith, chairman; R. H. Croll, vice-chairman; W. S. Heston, secretary; and James M. Wells, treasurer.

Officers for the coming year include: H. L. Cannell, chair-



Some of the Members of the Ohio State University Student Group
This Student Organization Affiliated with the Society Is Entering upon Its Second Year of Activity. The Accompanying Photograph Shows 21 of the 35 Active Members

NATIONAL MEETINGS CALENDAR

AERONAUTIC MEETING

Bellevue-Stratford Hotel, Philadelphia—Sept. 2 and 3

PRODUCTION MEETING AND EXPOSITION

Hotel Sherman, Chicago—Sept. 21-23

TRANSPORTATION AND SERVICE MEETING

Copley-Plaza Hotel, Boston—Nov. 16-18

TRACTOR MEETING

Chicago

ANNUAL DINNER

New York City—January, 1927

ANNUAL MEETING

Detroit—January, 1927

man; P. A. Harlamert, vice-chairman; E. G. Parks, secretary-treasurer; and Samuel Osborn, corresponding secretary.

The following studentss and faculty advisers are shown in the illustration on p. 7.

Back row, left to right; Prof. H. M. Jacklin, F. L. Hirsch, N. D. Veth, G. W. Pratt, J. W. Goetz, J. R. Haines, A. Hileman, M. B. Mantle, P. A. Harlamert, W. S. Heston, and Prof. C. A. Norman; front row; C. W. Smith, J. M. Wells, H. L. Cannell, E. G. Parks, R. S. Osborn, C. A. Stickel, H. Suffriti, K. R. Hagen, R. H. Croll, and R. Lucas.

Group members who were not present when the photograph was made are: J. M. Arburu, R. Q. Armington, H. C. Borneman, M. S. Klinck, H. S. Martin, W. A. Meiter, T. H. Metzler, P. D. Robinson, E. C. Schmidt, C. R. Terry, H. V. Ware, and M. D. Wiseman, and Profs. K. W. Stinson and John Younger, faculty advisers.

It is anticipated that during the coming year the Ohio State University Student Group will establish for itself a new record of achievement. The students and faculty members have the Society's best wishes for success.

TOPICS AT THE PRODUCTION MEETING

Conveyors, Gear Production, Inspection, and Machine-Tools To Be Discussed

Practically all features of the Society's annual Production Meeting have been arranged by the Committee of which V. P. Rumely is chairman.

THE SESSIONS

Addresses by experts will cover the design, installation and application of conveyors. The papers on this topic will be enlivened by the showing of motion-picture films and other illustrative material that will bring the spirit of mass production into the meeting.

A real Production Meeting would be incomplete without a thorough consideration of the many angles of gear manufacture. From the selection of raw material and through the machining and heat-treating processes, the automotive gear will be conducted by engineers who "know their groceries."

A paper on inspection along the line will open the Inspection Session. Following this, a symposium on interesting inspection devices will be held. A number of chief inspectors have already agreed to enter this symposium and will describe what might be termed "special gadgets" that have been found useful for inspection in their own plants but that are not known generally to other inspectors. Through the symposium a valuable interchange of information will be effected.

What Goes Wrong with Machine-Tools and Fitting the Tool to the Job will be the principal topics brought forth in the Machine-Tool Session. It is hoped that a very representative gathering of machine-tool men in the automotive industry and also from the machine-tool builders will be present to participate in the general discussion.

INSPECTION VISITS

At least two inspection visits will be included in the Production Meeting program, one of these being to the Kenosha plant of the Nash Motor Car Co., from which a cordial invitation to Society members and guests has been received. Other visits are being arranged.

THE STAG CARNIVAL

With Taliaferro Milton as chairman, the Chicago Reception and Entertainment Committee, including C. J. Blakeslee, W. J. Buettner, Lee W. Oldfield, C. A. Peirce, F. G. Whittington, and R. E. Wilson, has already under way arrangements for a Stag Carnival that will doubtless be the most colorful and entertaining social function of the eventful week in Chicago.

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S. A. E. Standards Committee and other standards activities are reviewed herein

STANDARDS COMMITTEE MEETING

Approval Given to 36 Recommendations Submitted at French Lick Springs

The regular semi-annual meeting of the Standards Committee was held at French Lick Springs, Ind., on June 1, with Vice-Chairman K. L. Herrmann presiding. The Division recommendations, as printed in the May issue of THE JOURNAL, were submitted for approval, with the exception of the recommendations on Army-Navy Standards, Lighting-Plant Ratings and Electric Incandescent Lamps. The remaining recommendations were approved by the Committee as submitted and were subsequently approved by the Council and at the Business Session of the Society.

Additional recommendations covering low-pressure pneumatic-tires and rims and high-pressure pneumatic-tire rims, not printed in the May issue of THE JOURNAL, were submitted for approval by the Tire and Rim Division. These recommendations were acted upon at an adjourned session of the Standards Committee, being approved as submitted with the addition of the 20 x 4-in. rim. The recommendations were approved also by the Council and at an adjourned Business Session of the Society held Thursday morning immediately preceding the Race Session.

Several of the recommendations, as submitted for Standards Committee approval, varied from the reports as printed in the May issue of THE JOURNAL. These changes are given in the accompanying list. With the exception of the report on low-pressure pneumatic-tire rims, the recommendations were not discussed in any detail and were not revised by the Standards Committee.

The final step in the approval of the recommendations by the Society is the letter-ballot of the voting members. In accordance with the Standards Committee Regulations, letter-ballots, returnable on July 24, will be sent to the voting members of the Society. In voting on the adoption of the recommendations it should be borne in mind that the recommendations as printed in the May issue of THE JOURNAL are submitted to letter-ballot with the changes and corrections given in the accompanying list, the page references being to the Division Reports as printed in the May issue of THE JOURNAL. In voting on the Tire and Rim Division recommendations, reference should be made to the discussion on these recommendations at the adjourned session of the Standards Committee given on p. 1.

AXLE AND WHEELS DIVISION REPORT

SOLID-TIRE FELLOE AND FELLOE-BANDS

(*Proposed Extension*, p. 411)

Caption for Table Should Read.—Dimensions of Bands and Wood Felloes for Solid-Tire Equipment.

First column should be omitted.

Brackets in second column should be omitted.

Dimensions for dual tires should be omitted.

Heading of last column should be changed to Wood-Felloe Thickness.

WOOD-SPOKES FOR PASSENGER CARS

(*Proposed Cancellation*, p. 411)

WOOD-SPOKES FOR MOTOR TRUCKS

(*Proposed Cancellation*, p. 411)

BALL AND ROLLER-BEARINGS DIVISION REPORT

INCH ROLLER-BEARINGS

(*Proposed S.A.E. Standard*, p. 412)

In the table of bearings arranged according to bore, the following corrections should be made:

Diameters 0.6950 and 0.7500 in., Bearing Nos. 09070-09194 and 09074-09194 respectively, reference letter *b* for dimension *R* should be *g*.

Diameter 1.3750 in., Bearing No. 2786-2720, the bearing number should be 2786-2729 and dimension *r* should be 1/32 instead of ⅛ in.

Diameter 1.4375 in., Bearing No. 44143-44348, dimension *b* should be 3.4834, not 3.4843 in.

Diameter 1.8125, Bearing No. 3595-3525, the bearing number should be 359S-3525.

Diameter 2¾ in., 2.2750 should be 2.7500 in.

Diameter 3.5000 in., Bearing No. 6500-6520, the bearing number should be 6580-6520.

Footnote *e* should read 2.4-in. taper per ft.

In the table of bearings arranged according to number, the following corrections should be made:

Bearing No. 359T-2525 should read 359-3525.

Bearing No. 2786-2720 should read 2786-2729 and dimension "*r*" should be 1/32 instead of ⅛ in.

METRIC ROLLER-BEARINGS

(*Proposed Cancellation*, p. 415)

ELECTRICAL EQUIPMENT DIVISION REPORT

GENERATOR MOUNTINGS

(*Proposed Revision*, p. 415)

A clearance radius of 4 in. should be specified for the No. 2 Bracket-Type Mounting.

STARTING-MOTOR MOUNTINGS

(*Proposed Revision*, p. 416)

STARTING-MOTOR PINIONS

(*Proposed Revision*, p. 417)

FLEXIBLE STEEL CONDUIT AND TUBING

(*Proposed Revision*, p. 417)

TIMER-DISTRIBUTOR MOUNTINGS

(*Proposed S.A.E. Recommended Practice*, p. 422)

INSULATED CABLE

(*Proposed Revision*, p. 419)

ENGINE DIVISION REPORT

PISTON-RINGS

(*Proposed Revision*, p. 422)

PISTON AND PISTON-RING OVERSIZES

(*Proposed Revision*, p. 422)

ENGINE SUPPORT ARMS

(*Proposed Revision*, p. 423)

STARTING-CRANKS

(*Proposed Revision*, p. 423)

CRANKCASE DRAIN-PLUGS

(*Proposed S.A.E. Recommended Practice*, p. 423)

The Engine Division plans to submit a supplementary report covering the hexagon dimensions for the

7/8 in.-18 pipe plug at the January meeting of the Standards Committee.

IRON AND STEEL DIVISION REPORT

Molybdenum Steels

(*Proposed S.A.E. Standard*, p. 426)

LIGHTING DIVISION REPORT

Head-Lamp Nomenclature

(*Proposed Revision*, p. 424)

Bases, Sockets and Connectors

(*Proposed S.A.E. Standard*, p. 425)

Head-Lamp Construction

(*Proposed S.A.E. Recommended Practice*, p. 425)

Items 10 and 13, referring to head-lamp distortion and reflection factor respectively, were withdrawn by the Division.

LUBRICANTS DIVISION REPORT

Crankcase Lubricating Oils

(*Proposed Revision*, p. 426)

The caption for the table reading: Proposed Crankcase Lubricating-Oil Specifications should read: Proposed Crankcase Lubricating-Oil Viscosity Numbers. The numbers adopted by Committee D-2 are to replace the tentative numbers used in the table.

MOTOR-TRUCK DIVISION REPORT

Hub-Odometers

(*Proposed Cancellation*, p. 427)

PARTS AND FITTINGS DIVISION REPORT

Brake-Lining

(*Proposed Revision*, p. 427)

1925 RADIATOR DIVISION REPORT

Radiator Nomenclature

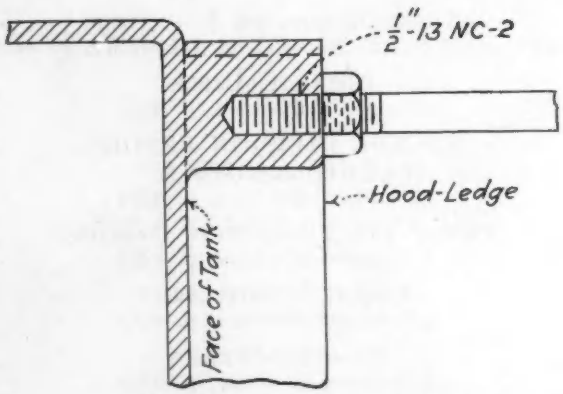
(*Proposed Revision*, p. 427)

The last six terms under Radiator Lower Tank should be included in a separate classification with the heading Radiator Assembly. This classification should follow the main heading Cast Type.

Tie-Rod Design

(*Proposed Extension*, p. 428)

The recommendation to cancel the present tie-rod fitting design was withdrawn by the Radiator Division preceding the Standards Committee Meeting and the adoption of an alternate design recommended, this design being as specified in the accompanying drawing.



Alternate Design of Radiator Tie-Rod

Water-Pipe Flanges

(*Proposed Revision*, p. 428)

SCREW-THREADS DIVISION REPORT

Screw-Thread Fits and Tolerances

(*Proposed Extension*, p. 428)

TABLE 1—LENGTH OF THREAD AND SHOULDER FOR FINE-THREAD SCREWS

Body Length (L)	LENGTH OF SHOULDER FOR DIFFERENT SCREW SIZES (Permissible Variation ± One Thread)												
	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4	1 1/2
3/8	....	....	....	....	....	....	....	....	....	....	....	....	....
1/2	....	....	....	....	....	....	....	....	....	....	....	....	....
5/8	....	....	....	....	....	....	....	....	....	....	....	....	....
3/4	1/8[a]	1/8[a]	....	....	....	....	....	....	....	....	....	....	....
7/8	1/4	1/8	1/8[a]	....	....	....	....	....	....	....	....	....	....
1	1/4[b c]	1/4	1/4	1/8[a]	1/8[a]	....	....	....	....	....	....	....	....
1 1/8	....	1/4[b c]	1/4	1/4	1/4	....	....	....	....	....	....	....	....
1 1/4	....	....	1/4[b c]	1/4	1/4	3/16[a]	3/16[a]	....	....	....	....	....	....
1 3/8	....	....	3/8[c]	3/8[b c]	3/8	5/16	3/16	....	....	....	....	....	....
1 1/2	....	....	....	3/8[c]	3/8	5/16	5/16	1/4[a]	....	....	....	....	....
1 3/4	....	....	....	....	[b]	1/2[b c]	5/16	1/4	1/4[a]	1/4[a]	....	....	....
2	....	....	....	....	....	....	9/16[b c]	1/2	1/2	1/4	1/4[a]	1/4[a]	....
2 1/4	....	....	....	....	....	....	....	3/4[b c]	1/2	1/2	1/4	1/4	1/4[a]
2 1/2	....	....	....	....	....	....	....	....	3/4[b c]	3/4	1/2	1/2	1/4
2 3/4	....	....	....	....	....	....	....	....	....	1[b c]	1/2	1/2	1/2
3	....	....	....	....	....	....	....	....	....	1[c]	3/4[b c]	3/4	1/2
3 1/2	....	....	....	....	....	....	....	....	....	....	1 1/4[c]	1 1/4[b c]	1
4	....	....	....	....	....	....	....	....	....	....	....	....	1 1/4[b c]
Usable thread..	5/8	23/32	13/16	29/32	1	1 3/32	1 3/16	1 3/8	1 9/16	1 3/4	1 15/16	2 1/8	2 1/2
Over-all thread	49/64	57/64	63/64	1 7/64	1 13/64	1 5/16	1 13/32	1 5/8	1 27/32	2 1/32	2 17/64	2 29/64	2 53/64

[a] For shorter body lengths, the thread shall extend to within $1/8L$ of the head.
[b] For this and longer body lengths the usable length of thread is $1\frac{1}{2}\ D + \frac{1}{4}$ in. and the over-all length of thread $1\frac{1}{2}\ D + \frac{1}{4}$ in. + 4 threads.
[c] Length of shoulder for rolled-thread screws only.

Extra-Fine Thread Fit Applications

(*Proposed Extension*, p. 431)

Wrench-Head Bolts and Nuts and Wrench Openings

(*Proposed S.A.E. Standard*, p. 431)

The Screw-Threads Division recommends also the adoption as S.A.E. Standard of Table 4 for Set-Screw Heads and Table 7 for Finished and Semi-Fin-

TABLE 2—LENGTH OF THREAD AND SHOULDER FOR COARSE-THREAD SCREWS

Body Length (L)	LENGTH OF SHOULDER FOR DIFFERENT SCREW SIZES (Permissible Variation ± One Thread)											
	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4
3/8	....	....	....	....	....	....	....	....	....	....	....	....
1/2	....	....	....	....	....	....	....	....	....	....	....	....
5/8	1/8[a]	....	....	....	....	....	....	....	....	....	....	....
3/4	1/8	1/8[a]	....	....	....	....	....	....	....	....	....	....
7/8	1/8	1/8	1/8[a]	1/8[a]	....	....	....	....	....	....	....	....
1	1/4	1/4	1/8	1/8	....	....	....	....	....	....	....	....
1 1/8	1/4[b c]	1/4	1/4	1/4	1/4[a]	....	....	....	....	....	....	....
1 1/4	1/4[c]	1/4	1/4	1/4	1/4	1/4[a]	1/4[a]	....	....	....	....	....
1 3/8	....	5/16[b c]	1/4	1/4	1/4	1/4	1/4	....	....	....	....	....
1 1/2	....	....	3/8	3/8	1/4	1/4	1/4	1/4[a]	....	....	....	....
1 3/4	....	....	[b]	3/8	3/8	3/8	3/8	3/8	3/8[a]	1/4[a]	....	....
2	....	....	....	[b]	3/8[b]	3/8[b]	3/8	3/8	3/8	1/4	....	....
2 1/4	....	....	....	....	....	9/16[b c]	5/8	1/2	3/8	1/4	1/4[a]	1/4[a]
2 1/2	....	....	....	....	....	....	5/8[b c]	1/2	1/2	1/2	1/4	1/4
2 3/4	....	....	....	....	....	....	....	3/4[b c]	1/2	1/2	1/2	1/2
3	....	....	....	....	....	....	....	....	3/4	3/4	1/2	1/2
3 1/4	....	....	....	....	....	....	....	....	3/4[b c]	3/4	3/4	3/4
3 1/2	....	....	....	....	....	....	....	....	....	3/4	3/4	3/4
3 3/4	....	....	....	....	....	....	....	....	....	1[b c]	1	1
4	....	....	....	....	....	....	....	....	....	....	1	1
4 1/4	....	....	....	....	....	....	....	....	....	....	[b]	1 1/4
4 1/2	....	....	....	....	....	....	....	....	....	....	....	1 1/4[b]
Usable Thread.....	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4
Over-all thread....	61/64	1 1/32	1 1/4	1 13/32	1 9/16	1 45/64	1 55/64	2 5/32	2 7/16	2 3/4	3 5/64	3 21/64

[a] For shorter body lengths, the thread shall extend to within $1/8L$ of the head.
[b] For this and longer body lengths the usable length of thread is $2\ D + \frac{1}{4}$ in. and the over-all length of thread $2\ D + \frac{1}{4}$ in. + 4 threads.
[c] Length of shoulder for rolled-thread screws only.

ished Jam Nuts as it is understood these parts are used to a considerable extent by the automotive industry.

Castle Nuts

(*Proposed Revision*, p. 435)

Screws, Bolts and Nuts

(*Proposed Revision*, p. 436)

The recommendation for the point of all finished and semi-finished bolts and cap-screws should read as follows:

> The points of all finished and semi-finished bolts and cap-screws shall be flat, chamfered 35 deg. to a plane normal to the axis of the screw passing through the point, with tolerances of plus 5 and minus 0 deg., the chamfer to extend to the bottom of the thread. The corner of the chamfer shall be rounded slightly.

A supplementary report, given in Tables 1 and 2, covering thread lengths for screws with body lengths too short to use the regular length of thread specified, was submitted by the Screw-Threads Division.

Machine-Screw Nuts

(*Proposed Revision*)

The Screw-Threads Division recommends that the present S.A.E. Standard for Machine-Screw Nuts, p. C6 of the S.A.E. Handbook, be revised to conform with the dimensions given in Table 9 of the Sectional Committee Report on Wrench-Head Bolts and Nuts.

TIRE AND RIM DIVISION REPORT

Pneumatic-Tire Rims for High-Pressure Tires

(*Proposed Revision*)

The Tire and Rim Division recommends that the present S.A.E. Standard for Pneumatic Tires on p. G1 of the S.A.E. Handbook be limited to pneumatic-tire rim dimensions, the nominal tire sizes to be included as supplementary information only.

Pneumatic-Tire Rims for Low-Pressure Tires

(*Proposed S.A.E. Recommended Practice*)

The Tire and Rim Division recommends for adoption as S.A.E. Recommended Practice the following rim dimensions for low-pressure pneumatic-tires, the nominal tire sizes given being included as General Information only.

Nominal Rim Diameter (Tire-Seat Diameter) In.	Nominal Rim Width, In.	Nominal Tire Sizes Used[1]
21	3½	29x4.40, 30x4.75
20	4	29x4.75, 30x5.25
21	4	30x4.95, 31x5.25
20	4½	30x5.77, 32x6.00, 32x6.20
21	4½	33x6.00, 33x6.20
21	5	33x6.75

[1] Tire sizes are not a part of this specification, but are given to show the regular tire sizes used on each rim.

Pneumatic-Tire Rim Sections

(*Proposed General Information*)

The Tire and Rim Division recommends that the present S.A.E. Standard for Pneumatic-Tire Rims on p. G3 of the S.A.E. Handbook, revised to agree with the standards adopted by the Tire and Rim Association of America, be continued as S.A.E. General Information only, a statement to the effect that the specification is in accordance with the standards of the Tire and Rim Association of America to be included in the specifications.

TRANSMISSION DIVISION REPORT

Transmission Nomenclature

(*Proposed Revision*, p. 436)

Group 1—Transmission should be first term.

Transmission case and Transmission case cover (when used as cover plate) should be the second and third terms.

Group 2—Shifting Mechanism should be inserted before the term Control housing.

Group 3 should be as follows

Group 3—Control
Control lever
Control-lever ball-handle
Control-lever ball-handle insert
Control-lever fulcrum ball

Group 4, Division XIII—Braking System, should be revised as follows:

Change Brake-lever segment (or sector) to Brake-lever sector.

Change Brake-lever pawl to Brake-lever latch.

Change Brake-pawl spring to Brake-latch spring.

Change Brake-pawl button to Brake-latch button.

Change Brake-pawl finger lever to Brake-latch spoon.

Change Brake-pawl rod to Brake-latch rod.

The following terms in Group 1—Clutching Parts, Division X, should be cancelled:

Clutch cone
Clutch-cone hub
Clutch-cone bushing
Clutch-spring spider
Clutch-spring stud
Clutch-spring retainer
Clutch-spring nut

The recommendation covering the Army-Navy Standards was not submitted to the Standards Committee for action as it was decided shortly before the meeting to withhold the report until the next Aeronautic Division meeting, which is to be held in the near future to consider the possibilities in aeronautical standardization. The recommendation on lighting-plant ratings did not meet with the approval of all of the Division members and it was consequently desired to have the Division reconsider the proposal before final action is taken. The Subdivision on Electric Incandescent Lamps held a meeting preceding the Standards Committee Meeting as a result of a criticism that had been received following the publication of the report in The Journal. Owing to a large number of changes that it is thought will be made during the next few months as a result of development work now under way, it was considered inadvisable to submit the report. The report will probably be ready for action at the January, 1927, meeting of the Standards Committee.

TIRE AND RIM REPORT REVISED

Discussion Indicates Need for Standardizing Tire Cross-Sections

The Division reports submitted for action at the Standards Committee Meeting on June 1 were, with the exception of the Tire and Rim Division Report, printed in the May issue of The Journal. The Tire and Rim Division Report, which was covered in a special article in the June issue of The Journal, p. 572, was approved by the Division subsequent to the publication of the reports in the May issue and was consequently acted upon at the Standards Committee without general circularization.

The recommendations printed in the May issue of The Journal were approved as submitted at the Standards Committee Meeting without extended discussion, but the Tire and Rim Division Report was discussed at length at both the regular meeting and at the adjourned session following the Business Session. The report of the Tire and Rim Division, revised as proposed following this discussion, is printed in full in the adjoining column in the summary of the recommendations approved at the Semi-Annual Meeting.

DISCUSSION AT STANDARDS COMMITTEE MEETING

H. M. CRANE[1]:—The report of the Tire and Rim Division is not presented as a final report, but with the idea of bringing out discussion. We have had many complaints from the tire people every time standardization has been attempted by the Society on the basis that we were attempting to dictate the manufacture of tires. We are interested primarily in interchangeability and that means standardization of the rim dimensions. We are not attempting to dictate the exact shape of the rim; that is a function of the Tire and Rim Association of America.

The Tire and Rim Division Meeting that was held at Detroit on May 7 was for the purpose of determining whether the wheel diameter had reached a point of stability or not. A study of the balloon-tire situation indicates that tire-sections are becoming more and more uniform, but we have had wheel diameters from 23 in. down to 19 in. by inch decrements in several of the tire-sections. The trend toward smaller wheels is obvious and that is one reason why we have made no effort toward standardization until now. The public are asking for low-appearing cars. A good many companies were limited by the road clearance, the brakes and other features of design as to how small they could make the wheels. Therefore, the reduction in diameter occurred in inch decrements.

At the Detroit Division meeting our examination showed that with one exception the rim dimensions for the old balloon-tire sizes, adopted as General Information in February, 1924, could still be used. These rim sizes with one change became what we are suggesting, 21 x 3½, 21 x 4, 20 x 4½, 21 x 4½, and 21 x 5. Although there was not a full attendance at the meeting, the members voted to present these sizes to the Standards Committee to bring out the present state of mind of the engineers on wheel diameters. If the engineers are convinced that wheel diameters will change next year to any considerable extent, we should hold up standardization for another year.

I would like to present this report in two parts. First, I will move that the form of table given in the proposed report be adopted. In this table the nominal rim diameters and widths are given. The tires that can be used with these rims are listed simply as supplementary information only.

[The motion was seconded]

B. J. LEMON[2]:—Does the motion refer to the method of listing rims or the method of listing tires or both? For instance, the rims are listed in the form 21 x 3½, but the tires are in the form 29 x 4.40. A different system is used for each.

MR. CRANE:—The intention is not to be specific about it. Any commercial and practical way of marking the tires would be satisfactory.

[The motion was carried]

I now move that the Society shall list as S.A.E. Recommended Practice the following rim sizes: 21 x 3½, 21 x 4, 20 x 4½, 21 x 4½, and 21 x 5. These sizes are recommended on the one sure basis for standardization, actual use. In volume of production and use, these rims are the ones that are now justified as standards. I would not be at all upset if somebody wanted to propose additional sizes, because my own opinion is that, if we standardize at all, we shall probably agree on a 20-in. wheel diameter, or possibly even a smaller diameter. The situation today and for 1927, from what we know, is such that we will not be justified in adopting the 20-in. wheel. For several of these rim sizes standards are established. We can either take these as they are, or wait a year and see what develops.

[The motion was seconded]

E. S. MARKS[3]:—I understand that the Firestone Tire & Rubber Co. and the Goodyear Tire & Rubber Co. recommend that we use a 4-in. instead of a 4½-in. rim for the 20-in. diameter and that a large number of companies are using it. If the tendency is toward the 4-in., I think Mr. Crane's suggestion of waiting another year might be entertained advantageously.

MR. LEMON:—The latest information the United States Rubber Co. has is that 10 manufacturers are using the 30 x 5.25-in. tire and 6, the 31 x 5.25-in. tire on the 4-in. rim. I should say that at least as many cars are using the 20 x 4-in. rim as the 21 x 4-in. rim and I would suggest including the 20 x 4-in. rim.

C. C. CARLTON[4]:—I think it is very unfortunate that this matter comes up at a time when most of the tire representatives have left the meeting. Owing to my business connection I am altogether unprejudiced. Therefore, any remarks I make are made only as a member of the Standards Committee. I think that it would be a very grave error for this Society to adopt today as recommended practice any list of sizes that is directly contrary to the practice of some of the leading automobile companies in the Country. Furthermore, in view of the coming of the 19-in. rim, which I personally believe will be used very largely within the next few years in this Country, and in view of my personal belief that the 20-in. rim will predominate eventually, I think that it will be a very grave error for the Society to adopt at this time any table of sizes specifying rim widths and diameters.

MR. CRANE:—I am not opposed to Mr. Carlton's point-of-view. We must recognize that the lack of uniformity in low-pressure pneumatic-tire sizes is a scandal; there is not any question about it. I do not care whose fault it is; the car engineers are just as much to blame as the tire engineers, if the engineers are to blame. The Society is on the defensive with regard to tire standardization and action should not be delayed any longer than necessary. The Division is not of the opinion that the 21-in. diameter is the ultimate size; in fact, we are very sure it will not be. The pressure is so great for a low appearance in automobiles that we will go to at least a 20-in., possibly to a 19-in., diameter. But if we are to continue inactive, we must have some real reason for our lack of activity which we can lay before the Division of Simplified Practice. I am depending on this meeting to bring out such reasons. If there is any way of having this question held over until this evening's meeting, I would be in favor of doing so.

R. S. BEGG[5]:—I move that Mr. Crane's motion be laid on the table.

[The motion was seconded and carried]

MR. CRANE:—I move that the Standards Committee Meeting adjourn subject to the call of the Chair.

[The motion was seconded and carried]

DISCUSSION AT ADJOURNED SESSION

CHAIRMAN K. L. HERRMANN:—I believe we have a quorum here to reconsider the motion laid on the table relative to the adoption of the report of the Tire and Rim Division. What is your pleasure relative to the action that we have taken?

L. A. CHAMINADE[6]:—I move that the 20 x 4-in. rim, and the 29 x 4.75 and 30 x 5.25-in. tires to be mounted on this rim, be included in the report. At least 3 companies, each with a very large production, are using the 29 x 4.75-in. tire and 9 or 10 companies, many of which are large producers, are using the 30 x 5.25-in. tire.

MR. CRANE:—I want to emphasize again the reason for presenting the table in this form. If you vote for the adoption of the 20 x 4-in. rim, the tire sizes follow automatically. In other words, if it is a fact that a tire that will go on the 20 x 4-in. rim is in commercial use, it should go in the table. If it is not a fact, it should not go in the table even though some might want to use it. The last column of nominal tire

[1] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

[2] M.S.A.E.—Automotive contact engineer, United States Rubber Co., New York City.

[3] M.S.A.E.—Chief engineer, H. H. Franklin Mfg. Co., Syracuse, N. Y.

[4] M.S.A.E.—Secretary and director of sales and advertising, Motor Wheel Corporation, Lansing, Mich.

[5] M.S.A.E.—Chief engineer, Jordan Motor Car Co., Cleveland.

[6] M.S.A.E. — Mechanical engineer, Studebaker Corporation of America, Detroit.

sizes used is intended to be exactly what it says it is, sizes that are used on the rims specified.

We dropped the idea of trying to standardize tire over-all dimensions. It cannot be done yet. We do think it is time that we at least take a step in obtaining interchangeability of tires. If it appears later on that we can select certain tires which will represent standard practice, we will do it, but we do not believe that it can be done for a year or two.

[The motion was seconded and carried]

MR. LEMON:—Some tire sizes listed might be reconsidered; for instance, the 30 x 4.95-in. tire is used by only one company and not in very large quantities. The 33 x 6.20-in. tire is only used as part equipment by one company. That size has never been of any importance at all.

MR. CRANE:—I do not think it is necessary for the Standards Committee to vote on the tire sizes. The form of presenting the information has been adopted. The standards of the Tire and Rim Association of America for the rim cross-sections are accepted by our recommendation.

I consider it is up to the Standards Department to find out what sizes actually are used in sufficient quantities to justify being included.

D. H. FENTON[7]:—If a car builder actually intends to go into production on a wheel other than the 21 or the 20-in. diameter, do you intend to include that rim diameter in such a table?

MR. CRANE:—Not now.

MR. FENTON:—The Willys-Overland Co. is now in production on a car using a 19 x 3½-in. rim. I recommend that we add the 19 x 3½-in. rim, and the nominal tire sizes used, the 27 x 4.40 and the 28 x 4.75-in. sizes.

MR. CRANE:—The proposed list represents the absolute minimum number of sizes. There is no objection to adding to this list, but we must remember that it will be judged by simplification not multiplication. We ought to adopt a rule that more than one company should use a size before it is included.

MR. FENTON:—I am not saying that there would not be justification on that score. It seems to me that the question is what you intend to accomplish by a table of this kind.

W. E. SHIVELY[8]:—If all the types and sizes that are being used at present were included, you would not be standardizing.

MR. CRANE:—I move the adoption of the report with the addition of the 20 x 4-in. rim.

[The motion was seconded]

J. E. HALE[9]:—I was not at the meeting this afternoon, but I understand that the proposal is based on simplification. From our point-of-view, that is what we want—simplification. I do not think we should talk standards so emphatically as we should simplification of sizes in combination with different rims. To publish the 30 x 4.95-in. tire, for instance, is a mistake. Anything we publish as recommended practice should be with the thought of simplifying the number of sizes necessary. To do some real constructive work that will lead to simplification, something should be set-up which, if it means anything to the automobile designer, will guide him to a definite point. It does not seem to me that this is definite enough. It gives some information from which we can pick out several different combinations, but it does not go far enough. On the other hand, I am convinced that the time has arrived when something definite can be accomplished.

I believe that we must have a certain range of tire cross-sections to carry different loads, and also that automobile designers will continue to differ as to the wheel diameter they use, because they will look at the axle clearance, the center-of-gravity and other factors differently. I think, however, that we ought to recognize the gradation or stepping-up of load capacities of tires. It is absolutely ridiculous to have 4.75, 4.95 and 5.25-in. tires. If you put them up against the wall and compare them, nobody here could tell one from the other because they are so nearly alike. Market conditions demanded them. The 5.77-in. tire is ridiculous because it is precisely the 6.00-in. tire.

If we are to be constructive we should make a definite recommendation of the rim widths that should be used with the different tire sections, after having decided upon the proper tire sections that are to be retained.

As submitted for action, the report has not gone far enough to do any real constructive work for the industry toward simplification. What we should talk about is simplified practice and it should not deal just with the rim sections; it should tie the rims up with the logical tire sections, leaving out sections that are superfluous. I object to any definite action on this report, believing that a better report can be drawn up.

MR. CRANE:—I have frequently laughed at specifying tire sections in hundredths of an inch and having them vary as much as ½ in. in the same sizes between different makes, but I cannot see really why Mr. Hale wants to stop the present movement, which is simplification of rims, until we can get the tire and car engineers to agree on the tire sections, because we do not know yet what the public wants. People are far from satisfied with the very low-pressure pneumatic-tire. We do not know how many plies should be used. The Tire and Rim Division would like to make a start by obtaining interchangeability of tires, and if we do that, we believe the tire people will get together.

[The motion was carried]

S.A.E. HANDBOOK WELL RECEIVED

Since the publication of the March, 1926, issue of the S.A.E. HANDBOOK, which was mailed during the first week in May, comments have been received from associations, Society members and purchasing agents complimenting the Society on the new form of issuing the S.A.E. Specifications.

The September issue of the S.A.E. HANDBOOK, which will be mailed during the early part of September, will contain the recommendations acted upon at the Semi-Annual Meeting of the Society and to be voted upon by letter-ballot of the voting members during the coming month.

In the September issue will be printed for the first time a section giving the changes made in the S.A.E. Specifications for that issue. This will enable members interested in certain specifications to tell promptly whether or not such specifications have been changed.

MAXIMUM BEAM CANDLEPOWER LIMITED

A general notice has been issued by Frank A. Goodwin, registrar of motor vehicles for the Commonwealth of Massachusetts, to the effect that on Sept. 1, 1926, certificates of approval previously issued for all head-lamps that project a beam of greater intenstiy than 50,000 cp. will be revoked. A general notice to this effect was issued in July, 1925, and reprinted in full in the July issue of THE JOURNAL, p. 34. The original date had been set for Jan. 1, 1926, but, owing to further time being necessary for certain manufacturers to change their designs and production processes, the time was extended.

AERONAUTIC STANDARDIZATION OUTLINED

A comprehensive outline of aeronautic standardization possibilities has been submitted to the members of the Aeronautic Division by Chairman E. P. Warner for determining upon a definite standardization program for the Division's work.

A meeting of the Division will probably be held in New York City on the day preceding the Aeronautic Meeting of the Society in Philadelphia on Sept. 2 to decide definitely on the standardization program. The outline as submitted by Professor Warner follows:

(1) *Engine Bearer Dimensions*.—With the coming of the radial engine, and especially with the pro-

[7] M.S.A.E.—Technical engineer, Fisk Rubber Co., Chicopee Falls, Mass.

[8] M.S.A.E.—Manager of tire design division, Goodyear Tire & Rubber Co., Akron, Ohio.

[9] M.S.A.E.—Manager, development department, Firestone Tire & Rubber Co., Akron, Ohio.

duction of small radial engines for use solely in non-military machines, agreement on the standardization of certain main elements of the mounting, facilitating interchanging engines of different types seems to be a possibility. The same is true of vertical and V engines supported on longitudinal bearers, especially in the smaller sizes where standardization could include the location of bolt-holes

(2) *Propeller-Hub Dimensions.*—Engines of approximately the same power and running at nearly the same speed might use satisfactorily uniform bolt-circle diameters, hub lengths and crankshaft tapers

(3) *Detachable Powerplant Mountings.*—It has been suggested that it may be possible in the near future to standardize the location of detachable powerplant mountings, increasing the ease with which the change from one type of engine to another can be made in an airplane having the powerplant detachable as a whole

(4) *Fuel and Oil-Pipe Dimensions.*—Fuel and oil-pipe dimensions are now specified by the Army and Navy Air Services, but the specifications apply particularly to engines of 150 hp. and more. With the prospective production and use of smaller and lighter engines there is a possible field of interest for commercial standardization

(5) *Fuel and Oil-Tank Outlets and End Fittings.*—A special need exists for the standardization of hardware in commercial machines to reduce production costs when the production of a single design is comparatively small

(6) *Fuel-System Controls.*—Fuel-system controls are sometimes confusing to a pilot operating a new machine, even though the significance of the various settings of the valves is indicated by markings. Some degree of standardization of valve-control positions and markings may be possible

(7) *Fuel-Gage Mounting.*—The mountings of fuel gages could be simplified if the size and type of opening in the tank could be standardized, making the depth of the tank the only important variable between different gages and permitting interchangeability in emergency, even with gages not calibrated for exactly the same depth, and therefore giving only relative indications

(8) *Radiator Connections.*—Connections in the cooling-system, like those in the fuel and lubricating systems, might be standardized in terms of the size of engine, eliminating the use of reducing bushings and any unevenness in fit where hose connections are used

(9) *Radiator Mountings.*—The standardization of radiator mountings and detachments is among the possibilities when nose radiators are used. Like the standardization of powerplant mountings, however, it seems to present great difficulties, far greater than those attending standardization in several other lines.

(10) *Starting-Motor Drives.*— Manifestly, anything that can be done to reduce the number of special types of starting-motor that have to be built for special adaptations would tend to reduce both first costs and servicing troubles

(11) *Wheels and Tires.*—A considerable degree of standardization of wheels already exists, but further standardization should be considered, especially with reference to agreement on standard hub length, rim dimensions, inner-tube valve stems, fairing-discs, hub-caps, and mountings

(12) *Shock-Absorber Cord Rings.*—The occasional, and perhaps growing, use of shock-absorber cord made up in ring form warrants standardization of certain types of such ring to reduce the stock necessary to meet replacement demands

(13) *Rubber Pads for Shock-Absorption.*—The rubber pads that have gained so much favor for shock-absorption can be made in a wide variety of diameters, thicknesses and bores. Standardization possibilities are indicated

(14) *Tail-Skid Shoes.*—Wide variation of form of tail-skids offers a considerable obstacle to the standardization of shoes, but the rapidity with which such shoes wear out, and the frequency with which they have to be replaced, would make concentration on standard forms very useful even if several standards of radically different shapes had to be adopted to fit different groups of skids

(15) *Safety-Belt Attachment.*—Where the safety-belt attachment is made by a strap through a loop of wire, standardizing may not be necessary. Mounting and interchangeability would often be facilitated, however, especially where belts for one or two persons may have to be fitted interchangeably in the same cockpit, by standardizing the width of belt and possibly some elements of the end terminal.

(16) *Air-Speed Meter Connections.*—It has been suggested that the tubes on air-speed meters and the heads might always be of a standard size, or at least of one, two or three standard sizes. Another conceivable field of standardization is the ratio between the dynamic head and the pressure provided by the venturi or the pitot-venturi meters. If that pressure could always be brought to a close approximation to one of a few standard values, it would no longer be necessary to use a venturi air-speed head with a specially designed meter

(17) *Instrument Mounting.*—The interchangeability of instruments on a board, frequently desirable, would be facilitated if a few sizes of dial and types of mounting plate and location of holes in the flange could be agreed upon

(18) *Rolled and Extruded Duralumin Sections.*—The increasing use of rolled and extruded duralumin sections suggests possible economies if the number of special sections could be reduced to the minimum by agreeing on a series of standard sizes in each of several standard forms. Standardization in this field seems almost inevitable in the future if the use of light alloys continues to develop

(19) *Streamline Steel-Tube Dimensions.*—The same arguments as in (18) apply to the standardization of streamline steel-tube dimensions and forms, both for economy and in order that tubes from any mill may fit the same end-terminals

(20) *Special Alloy-Steels.*—At times it may be desirable to use in aeronautic work special steels at present not included in the list of S.A.E. Iron and Steel Specifications. If this seems to be of sufficient importance, the possibility of extending the present specifications could be taken up with the Iron and Steel Division

In submitting this outline to the members of the Division, Professor Warner has asked for the opinion of the members on the following questions with reference to each of the subjects discussed.

(1) Does this appear to be a desirable subject for standardization, either now or in the future?
(2) If so, should standardization be undertaken now or in the near future?
(3) Or should any attempt at securing agreement be postponed until some later date?
(4) If standardization is desirable now, do you con-

sider the Society the logical body to undertake the work?

(5) Or is it to be expected that some governmental organization will do it?

As it is desired to determine upon a standardization program that will meet with the consensus of opinion of the industry, suggestions of Society members with reference to the subjects discussed will be appreciated by the members of the Aeronautic Division.

ARMY-NAVY AERONAUTIC STANDARDS

Leslie MacDill and R. S. Barnaby Make Statement on Standardization Procedure

Major Leslie MacDill, U. S. A., chief engineer of the Air Service, and Lieut. R. S. Barnaby, of the Bureau of Aeronautics, Navy Department, have issued a statement covering the procedure followed in developing the Army-Navy or so-called AN Standards for aircraft parts. The statement reads, in part, as follows:

The Army Air Service and the Bureau of Aeronautics of the Navy Department are now issuing the first of a new series of drawings for standard parts. These drawings, known as AN Standards, represent parts that have been standardized by the Army Air Service and the Bureau of Aeronautics of the Navy Department. They represent the first result of the labors of a joint committee consisting of representatives of the two Services appointed by their respective chiefs for this purpose.

To the meetings held by this committee are invited representatives from the various airplane building companies, manufacturers of materials and parts for aircraft, and the Aeronautic Division of the Standards Committee of the Society of Automotive Engineers. In this way the industry has been well represented, and it is largely due to their cooperation and assistance that the AN Standards have become possible.

The advantages of such standardization are manifold. During the war, when the Services were buying airplanes and parts in large quantities, it was necessary that standards should be adopted rapidly. This was done by the Services independently. Naturally the results obtained were different. These differences have persisted, and as a result an Army turnbuckle, bolt or similar part has been just a little different from a Navy part used for the same purpose; different enough, however, so that a Navy inspector could not accept the Army part and vice-versa. This required the part manufacturers to produce and carry duplicate stocks, and made it necessary for the airplane builders doing work for both Services to purchase and maintain two separate stocks. From the service point of view it represented an increased cost and prevented the exchange of material between the Services. It is the purpose of the AN Standards to eliminate these conditions.

The Society of Automotive Engineers, through the Aeronautic Division of the Standards Committee, is planning to use the AN Standards as a basis for future standards for civil aviation.

Naturally changes on such a large scale must be adopted gradually, and effected so as to entail the minimum of confusion and financial loss. It is believed that the Navy's method of accomplishing this is explained clearly in the following excerpts from a letter from the Bureau of Aeronautics accompanying the AN Standard drawings addressed to inspectors of naval aircraft and to the Naval Aircraft Factory:

(1) As a result of conferences between representatives of the Army Air Service and the Bureau of Aeronautics, an attempt is being made to standardize the specifications and drawings for aeronautical material and fittings. It is hoped that in time this will include all materials, the so-called "standard parts and fittings," and equipment common to the two services.

(2) The resulting specifications and drawings will be known as AN or Army-Navy Standards. In the case of the drawings it is intended that they shall supersede the corresponding Naval Aircraft Factory drawings in the Standard Catalog. The AN Specifications will serve as master specifications for the preparation of new Navy Department Leaflet Specifications for the material or parts concerned.

(3) To facilitate the use of the AN Standard drawings a conversion list has been prepared showing the corresponding AN number for every Naval Aircraft Factory part number for which an AN Standard exists.

(4) It is requested that the AN Standard drawings be inserted in the front section of the Standard Catalog and that the corresponding Naval Aircraft Factory drawings, as shown on the list accompanying the drawings and entitled Old Standard Drawings with Corresponding AN Standard Drawings That Supersede Them, be removed and destroyed.

(5) One of the precepts of the committee in developing the AN Standards was that their adoption should not cause loss or difficulty to the manufacturers on account of stocks of old standard parts and materials. This applies to the manufacturer of the material or parts as well as to the aircraft builder. With this in mind it was endeavored to keep the new AN Standard parts interchangeable with the old wherever possible. Accordingly, it was agreed that the promulgation of the AN Standards should not prevent the airplane builders from using the old material that they have in stock or may be required to purchase in the near future.

(6) This last provision is necessary in order to work no undue hardship on the material or parts manufacturer. For his case it was decided that he should be permitted to supply on orders calling for AN Standards, material or parts conforming to the old requirements until his supply is exhausted, unless by special agreement between manufacturer and purchaser it is desired to furnish the AN Standard parts. It is intended, however, that the above shall apply only to parts manufactured before promulgation of the AN Standards, and that in the future such parts shall be made in conformity with the latter.

(7) Inspectors shall see that after the date of promulgation new stocks of parts are manufactured in accordance with the AN Standards for use on Navy contracts.

(8) The date of promulgation for the AN Standard drawings included in the present list is July 1, 1926.

The Army Air Service has found it desirable at this time to issue an entirely new Standards Book that will include the AN Standards. This book is distributed to all Air Service contractors and inspectors. The preface to this book includes the following paragraphs that outline the attitude of the Air Service regarding the use of old standard parts:

The issue of this new Standards Book does not automatically render obsolete any stock on hand that is listed in the old book but not included in the new one. The old stock will be used for replacement in the Air-Service equipment already in use and may be used in new articles until the stock on hand at contractors' plants is exhausted.

Old stock covered by numbers in the New Standards Book is to be identified on new drawings by the new part number. Stock made up to the

old standard-parts drawings is to be accepted on orders specifying the new numbers until the supply on hand at the part manufacturers' plants at the time of issue of this book has become exhausted.

It may be easily realized that the field of AN standardization is almost without limit. The work started as an attempt to do away with the differences between the material specifications of the two Services. It was soon apparent that this was only a small part of the subject. The next most obvious field was in the so-called "standard parts" such as bolts, nuts, pins and washers. These fields, and the field of powerplant equipment and fittings, have only been partially covered. General equipment has been barely touched. With the promulgation of the first AN Standard drawings, however, the ground has been broken and the work should advance rapidly from now on.

MOLYBDENUM STEELS HEAT-TREATMENT

S.A.E. Steels 4130 and 4140 Covered by Iron and Steel Division Report

At the May meeting of the Iron and Steel Division members in Bethlehem, the accompanying report of the Subdivision on Physical-Property Charts covering notes and instructions for S.A.E. Molybdenum Steels 4130 and 4140 was approved. S.A.E. Steels 4150 and 4615 are not included, but will be covered in a report that will be submitted at a later date.

NOTES AND INSTRUCTIONS FOR MOLYBDENUM STEELS

S.A.E. STEEL 4130

These notes are not to be considered in any way a part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.25 - 0.35
Manganese	0.40 - 0.70
Phosphorus	0.040 max.
Sulphur	0.045 max.
Chromium	0.50 - 0.80
Molybdenum	0.15 - 0.25

This steel may be used interchangeably with Steels 2330, 3130, 3135, and 6130 for heat-treated automotive forgings requiring greater strength and toughness than are obtainable with plain carbon-steels.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 4130-*VI*

(1) Heat to 1550 to 1650 deg. fahr.
(2) Quench
(3) Draw to required hardness

Heat-Treatment 4130-*VII*

(1) Normalize at 1650 to 1750 deg. fahr.
(2) Reheat to 1550 to 1650 deg. fahr.
(3) Quench
(4) Draw to required hardness

For forgings that are to be machined after heat-treatment, Heat-Treatment VII is recommended.

S.A.E. STEEL 4140

These notes are not to be considered in any way part of the standard specifications for S.A.E. Steels. They are added solely for the information of users of the steels and the guidance of purchasers in the selection of proper materials for different purposes. They should not be incorporated in the customer's specifications when ordering steel.

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.35 - 0.45
Manganese	0.40 - 0.70
Phosphorus	0.04 max.
Sulphur	0.045 max.
Chromium	0.80 - 1.10
Molybdenum	0.15 - 0.25

This steel may be used interchangeably with Steels 2340, 3140 and 6140 for heat-treated automotive forgings requiring greater strength and toughness than are obtainable with plain carbon-steels.

As the structure of forgings is less uniform than that of bar stock in most cases, either in the individual piece or between different pieces, normalizing as in Heat-Treatment VII is recommended as the preliminary treatment for all forgings, but the desired physical properties of bar stock can be obtained generally without normalizing, as in Heat-Treatment VI.

Heat-Treatment 4140-*VI*

(1) Heat to 1525 to 1625 deg. fahr.
(2) Quench in oil
(3) Draw to required hardness.

For all general requirements Heat-Treatment VII is recommended.

Heat-Treatment 4140-*VII*

(1) Normalize at 1650 to 1750 deg. fahr.
(2) Reheat to 1525 to 1625 deg. fahr.
(3) Quench in oil
(4) Draw to required hardness

Parts that are to be machined after forging and before heat-treatment, Heat-Treatment VIII is recommended.

Heat-Treatment 4140-*VIII*

(1) Normalize at 1650 to 1750 deg. fahr.
(2) Reheat to 1250 to 1350 deg. fahr.
(3) Cool slowly
(4) Machine
(5) Reheat to 1525 to 1625 deg. fahr.
(6) Quench in oil
(7) Draw to required hardness.

WOODRUFF KEY STANDARD PROPOSED

Subsequent to a general conference held on March 16 to discuss standardization of Woodruff keys at which it was voted as the sense of the conference to do so by a Sectional Committee organized under the procedure of the American Engineering Standards Committee, a Subcommittee of the Sectional Committee on Standardization of Shafting, sponsored by the American Society of Mechanical Engineers, was organized at a meeting held in Detroit on May 12. The proposal of the British Engineering Standards Association restricting such a standard to 32 key sizes was discussed in conjunction with the possible international standardization of these keys. The report of the Subcommittee of the American Sectional Committee when drafted will be circularized for study and comments by the industries.

Audibility Anti-Knock Tests and Knock-Intensity Evaluation

By DANIEL ROESCH[1]

CHICAGO SECTION PAPER *Illustrated with* PHOTOGRAPHS, DRAWING AND CHARTS

ABSTRACT

VALUABLE data pertaining to the anti-knock qualities of fuels, combustion-chamber shapes and the efficiency of gasoline dopes are believed to be obtainable by the method described. Several hundred tests have failed to show anything seriously wrong with the method; on the contrary, involved matters such as the relative effect of various anti-knock fuels, anti-knock dopes, altitude, compression, mixture-ratio, and cylinder actions, have become clearer. No apparent reason exists why the method is not applicable to the determination of the relative merits of combustion-chamber shapes, various spark-plug locations and other important considerations necessary to the realization of higher compression-pressure and its accompanying substantial fuel-saving. Further, the incidental information gained concerning engines of present-day compressions is of no small value.

As an example of its application, the method has been used to appraise the value of anti-knock dopes or fuels, and to determine the quantities necessary to produce equivalent anti-knock results. Evidently, the proportional blends can be determined conclusively. Refining processes can be surveyed from the anti-knock viewpoint and the data used as aids in the writing of refinery control-specifications. Inspections by this method of many proposed anti-knock dopes have shown their effectiveness or ineffectiveness. Apparently, the method is applicable either to knock-suppressers or to knock-inducers, as shown by the several knock-suppressing tests and the normal butyl nitrite knock-inducer test. In the method as used, the effect of the personal equation is more imaginary than real. A certain technique is necessary, but check results are repeatedly obtained with unknown fuels and indiscriminate change-overs of the testing engineer during the series of test runs on any fuel have been made by Prof. H. S. White[2] and the author with the same results as though the test were completed by one engineer. It is stated by the author that the purpose of the paper will be fulfilled if the limitations as well as the advantages of the test-method are brought out by the discussion.

ALL internal-combustion-engine fuels have specific knocking-properties that affect the limits of compression and, consequently, the power and the economy of the engine. One of the most important problems that confronts the automotive engineer today is the determination and suppression of the knocking or pinking tendency of these various fuels. Knowledge of these properties should disclose the fuels that are suitable for high compressions, resulting ultimately in improved engine-design and better fuel-economy, and the object of the paper is to demonstrate the method adopted in the automotive laboratory at the Armour Institute of Technology, Chicago, for ascertaining this information, as well as to present and analyze the results obtained from an extended series of tests.

When an improved fuel is used in a present-day engine, a reduction in fuel consumption can be expected since the spark-advance frequently is kept in a retarded position to take care of wide-open-throttle conditions of operation while using fuels of a poorer grade. Failure to advance the spark for lighter loads becomes a habit and results in decreased mileage per gallon of fuel. The reduction in fuel consumption may be 25 per cent, for an improved fuel when used in an engine having a high compression-ratio, and this corresponds to an annual saving of about 2,000,000,000 gal. of gasoline in the United States alone.

A "knock" sedative may take the form of a gasoline dope, a made-to-order gasoline or a design of combustion-chamber that will burn offending commercial gasoline or fuel without knocking. All three methods of knock-suppression have been investigated aggressively and offered to the motoring public with similar aggressiveness. The fuel admixtures have been many and they vary greatly in their effectiveness. Some appear to meet every driving or engine condition in a satisfactory manner, while others are less effective. Besides their effect on noise, they have educated the public to a new standard that is now demanded. The made-to-order gasolines seem to have entered the field strongly as anti-knock fuels. Some of the cracked fuels in particular have met with much favor, and to expect that made-to-order chemical fuel-structures will continue to hold and to increase their favor in this respect is a reasonable conclusion. The density specification for motor fuels has been displaced in recent years by the distillation specification, and we can expect the latter to be displaced or augmented by a chemical-structure classification.

Combustion-chamber design has been investigated rather thoroughly with respect to the anti-knock qualities of various shapes. In general, we can expect a T-head engine to knock more than an engine having a combustion-chamber that approaches the spherical shape. Special features, such as the Ricardo head that has an inherent turbulence-factor, have their own valuable features with respect to knocking.

One phase of the general study of these three methods of reducing knock is that engines or dopes having good anti-knock characteristics with fuels of today may have different relative anti-knock values with fuels of the future.

TESTING APPARATUS EMPLOYED

The fuels tested were used in a four-cylinder poppet-valve automobile engine having an L-head combustion-chamber and a compression-ratio of 4.5. The engine was fitted with an MI Stromberg carbureter having means for regulating the light-load and the full-load mixtures. A fixed carbureter-adjustment was used except as indicated, since only a limited fuel-supply was available usually for test and this prevented extended

[1] M.S.A.E. — Associate professor of automotive engineering, Armour Institute of Technology, Chicago.

[2] M.S.A.E. — Assistant professor of automotive engineering, Armour Institute of Technology, Chicago.

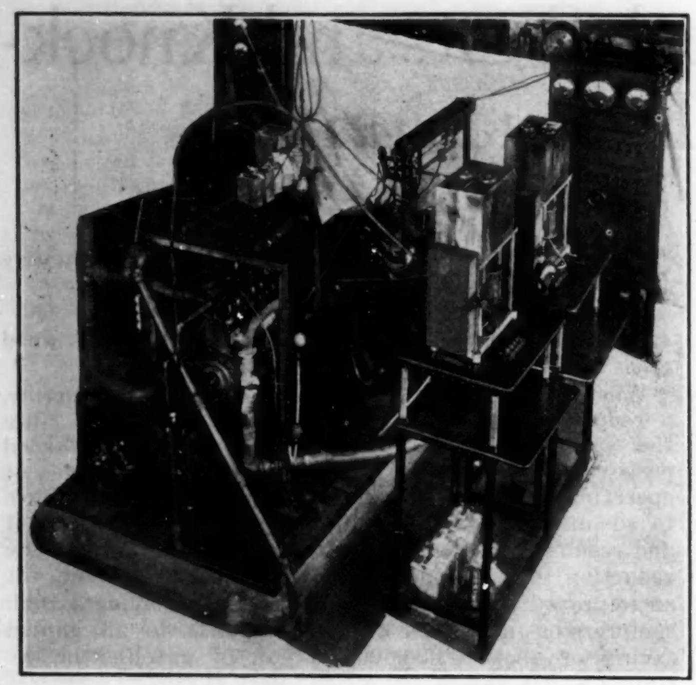


FIG. 1—FUEL-TESTING APPARATUS EMPLOYED
A Four-Cylinder Poppet-Valve Automobile-Engine Having an L-Head Combustion-Chamber and a Compression-Ratio of 4.5 Was Connected Flexibly to a Sprague Electric Co. Cradle-Dynamometer by a Double Universal-Joint. Customary Approved Methods of Determining Speed and Torque and Air, Water and Oil Temperatures Were Provided. A Fixed Carbureter-Adjustment Was Used Except as Indicated in the Paper

investigations of mixture-ratio and of variation in viscosity, density and heating value of the fuel. The engine was connected flexibly to a Sprague Electric Co. cradle-dynamometer by a double universal-joint as shown in Fig. 1. Customary approved methods of determining speed and torque and air, water and oil temperatures were provided. The spark-advance readings were obtained from a double-insulated spark-fanning-out device directly connected to one cylinder of the engine. The device could be read to less than 0.5 deg. of crankshaft movement and was in operation continuously. The fuel consumption was determined by an electrically operated fuel-weighing machine. In the case of water-feed tests, an additional machine was used for the rate of water feed by weight.

One of the weighing machines is shown in Fig. 2 and the wiring diagram is depicted in Fig. 3. The machine has incorporated in it a readiness-to-test feature that automatically holds the device in readiness to start a test while the other preliminary preparations are being made.

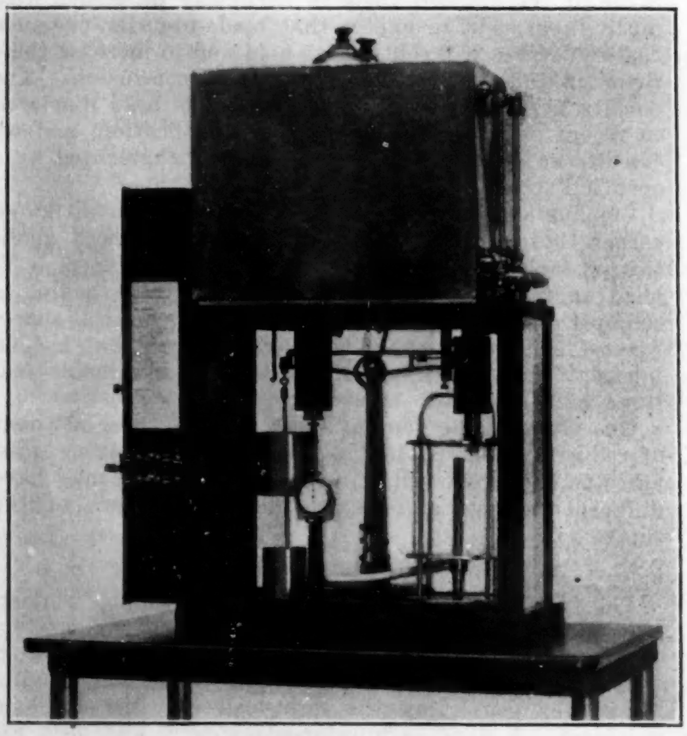


FIG. 2—TYPE OF WEIGHING MACHINE
The Machine Automatically Is Always in Readiness To Start a Test While the Other Preliminary Preparations Are Being Made

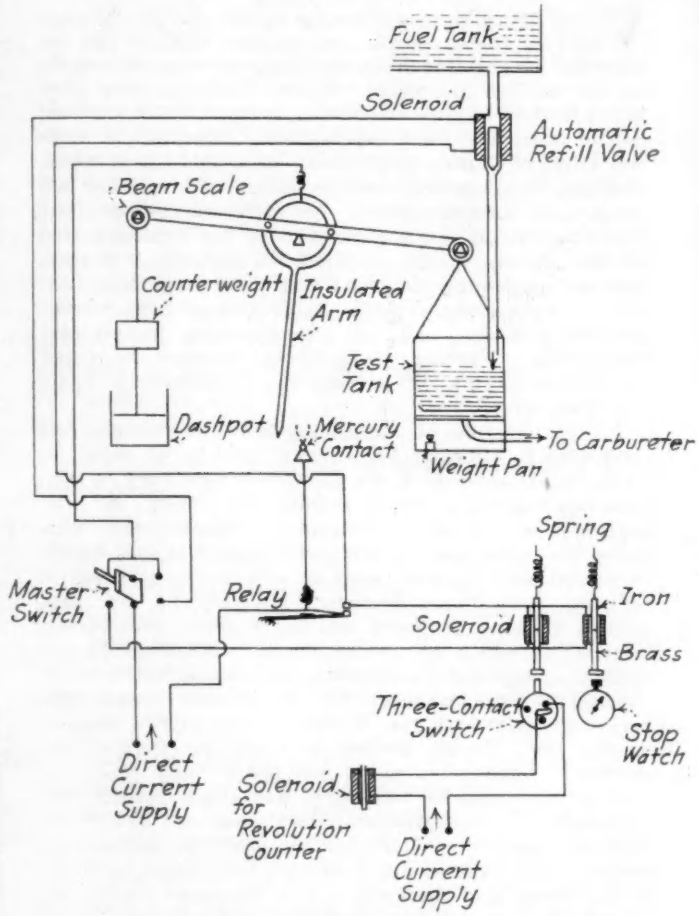


FIG. 3—WIRING DIAGRAM
The Manner of Connecting the Fuel-Weighing-Machine Controls Is Shown

The sensitiveness permits runs to be made with as little as 0.025 lb. of fuel or water. The limit of accuracy can be adjusted by selecting the length of run. The general set-up is shown in Fig. 1, under the conditions of using gasoline and water and employing one weighing machine for each liquid.

AUDIBILITY TEST-METHOD FOR ANTI-KNOCK FUELS

Many test-methods of evaluating the relative merits of fuels with regard to their anti-knock qualities have been employed. Some methods have been applied directly to the engine and this, in many respects, is a most desirable feature; others have been indirect and necessitate knowing the relation of the test-method to actual engine-performance. The method used in these tests of various fuels and mixtures is one of direct application. While the method proposed is not claimed to be the most precise, it is claimed to have great potential and considerable

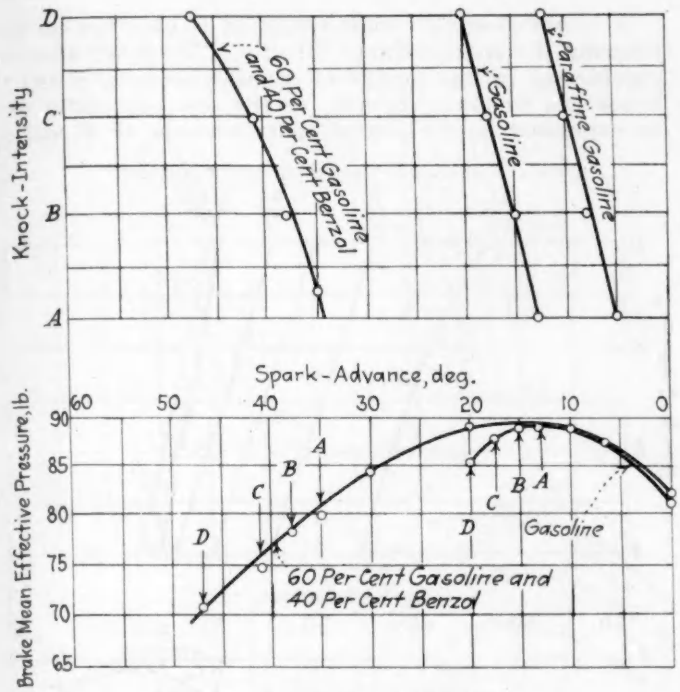


FIG. 4—REPRESENTATIVE FUEL-DATA
It Is Believed That the Olefins, Napthenes, Aromatics, Alcohols, and the Like Will Be Disposed to the Left of the Curve Designated 'Paraffine Gasoline" in the Order Named. The Lower Curves Show the Power Characteristics as Well as the Knock-Intensities of the Commercial Gasoline and the 60-40 Mixture of This Gasoline and a Benzol

intrinsic value. The potential value has been developing rapidly into actual value.

The test-method developed in our automotive laboratory has been used with many commercial fuels and, while the various modifying factors have not all been investigated, many valuable comparative tests have been made. The data warrant further investigations, and these are now being conducted. Special tests were made for this paper, primarily to illustrate the method and secondarily to show the results obtained when investigating:

(1) "Ethyl-fluid" treatment
(2) Gasoline-benzol mixtures
(3) Water-feed into the manifold
(4) Part-throttle effects under variable compression and under variable altitude or barometer
(5) Air admixtures under variable compression
(6) Carbon deposits

The results should not be used without consideration of the conditions of test, since the carbon deposits in the engine will affect the results during the test, as will also the barometric pressure. In no case was the carbon deposit considered excessive nor was the barometer variation more than 1 in. of mercury. A variation in knock-intensity was, however, easily detected for either of the above ranges in engine operating-condition. This fact is considered favorable to the sensitiveness of the method in detecting small differences in fuel characteristics or combustion-chamber shapes. The latter investigation requires a standard fuel, while the former requires a standard combustion-chamber. The results obtained indicate that considerable confidence can be placed in the method. Further investigation contemplates an improvement in the audibility measurements and continued study of modifying factors.

Means are provided for determining the torque, the speed, the fuel consumption, and the spark-advance while operating at wide-open throttle and a constant speed of say 1000 r.p.m. Optional runs are made at partly closed throttle and at other speeds. Test runs usually are made with the mixture set for approximately maximum power.

Test runs are made at various spark-advances from dead-center, advancing step-by-step until the maximum permissible knock occurs. Observations to obtain the desired data are recorded and the carbureter air, oil, jacket-water, and other conditions are maintained constant for all runs. The knock-intensity is determined by the listening method, using the following code:

KNOCK-INTENSITY CODE

Designation	Knock-Intensity
A	First indication
B	Slight
C	Medium
D	Sharp
E	Severe

Considerable time and study were devoted to the development of the code of knock-intensities; while to explain the code is rather difficult, reasonably accurate check-results are obtained by different testing-engineers or by the same engineer when checking unknown fuels. In practice, no difficulty has been experienced in having a different engineer take over the testing at any point in the series of runs, and further information regarding the effect of the personal element is presented in the Appendix. The primary results are plotted in two ways; first, with knock-intensity versus spark-advance and, second, with corrected brake mean-effective pressure versus spark-advance.

Representative data are shown in Fig. 4 for a "para-

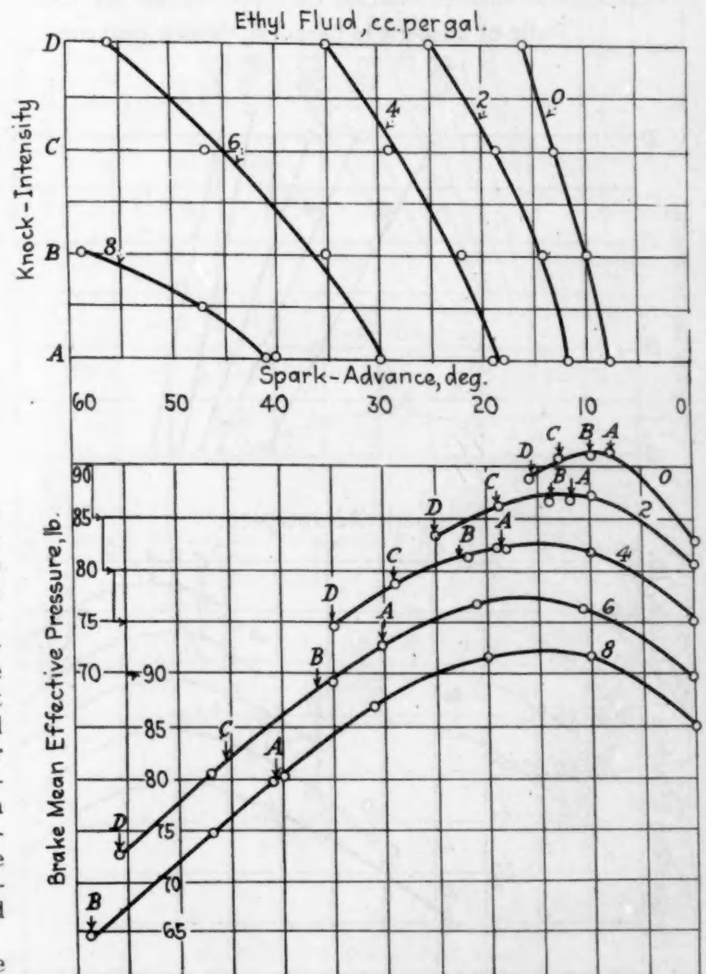


FIG. 5—GASOLINE AND ETHYL-FLUID MIXTURES
The Result of Using Raw Gasoline and Various Increasing Amounts of Ethyl-Fluid Are Shown

ffine" gasoline. It is believed that the olefins, naphthenes, aromatics, alcohols, and the like will be disposed to the left of this curve in the order given, although not all these fuels have been tested. A commercial gasoline is shown and a 60-40 mixture by volume of this same gasoline and a benzol. The lower curves of Fig. 4 show the power characteristics as well as the knock-intensities of the commercial gasoline and the 60-40 mixture of this gasoline and a benzol.

Method of Evaluating the Knock-Intensity

The *P*-and-*R* Index *A* was first suggested by E. B. Phillips[3] as a means of giving a numerical value to the anti-knock properties as shown by the graphical presentation and method of test procedure I have developed. The result is an arbitrary figure based on relative areas and is determined as follows. The area between the knock-intensity curve, the zero-degree spark-advance line, the *A* knock-intensity line and the *D* knock-intensity line is divided by the total area bounded by the zero and the 60-deg. spark-advance lines and the *A* and the *B* knock-intensity lines. This value, expressed as a percentage, is used as the *P*-and-*R* Index *A*. It usually is equal numerically to the value obtained by determining the spark-advance represented by the conditions midway between the *B* and the *C* knock and dividing this spark-advance by 60. Since the knock-intensity lines are not always straight, this method cannot be applied directly, but slight curvatures can be approximated closely and readily.

[3] Chief chemist, Sinclair Refining Co., East Chicago, Ind.

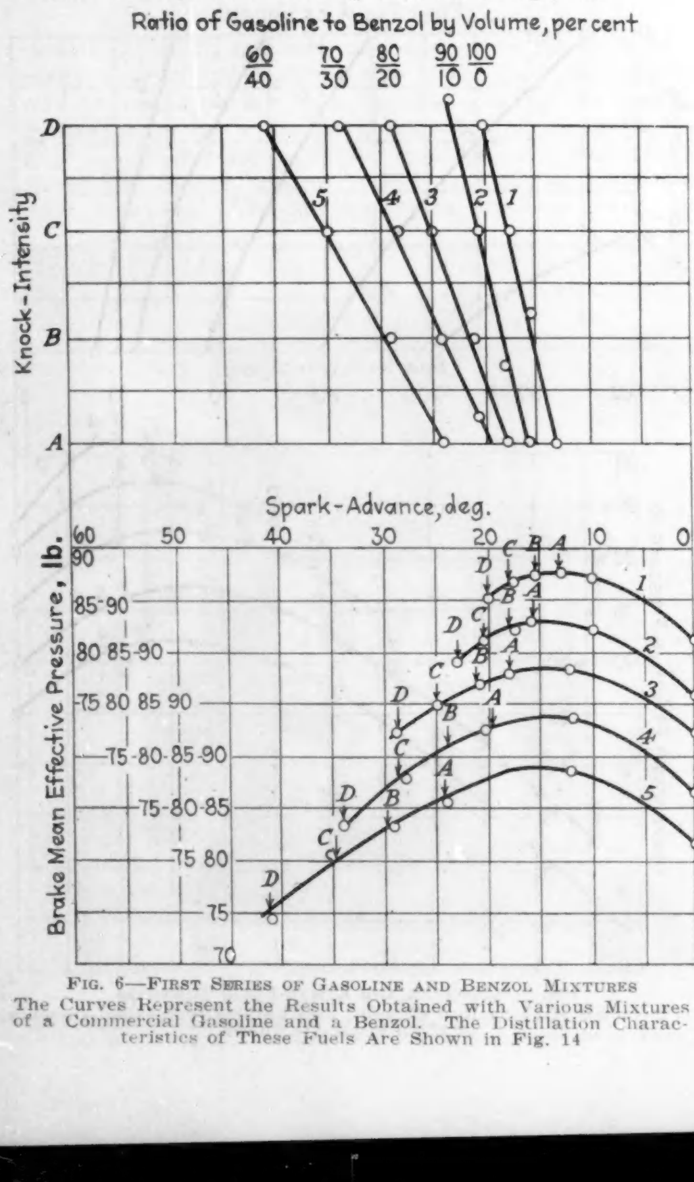


FIG. 6—FIRST SERIES OF GASOLINE AND BENZOL MIXTURES
The Curves Represent the Results Obtained with Various Mixtures of a Commercial Gasoline and a Benzol. The Distillation Characteristics of These Fuels Are Shown in Fig. 14

A second *P*-and-*R* Index-valuation is obtained by expressing the spark-advance directly. The spark-advance represented by the conditions midway between *B* and *C* knock can be taken directly, or the knock-intensity can be expressed by the actual spark-advance at *B* and *C*

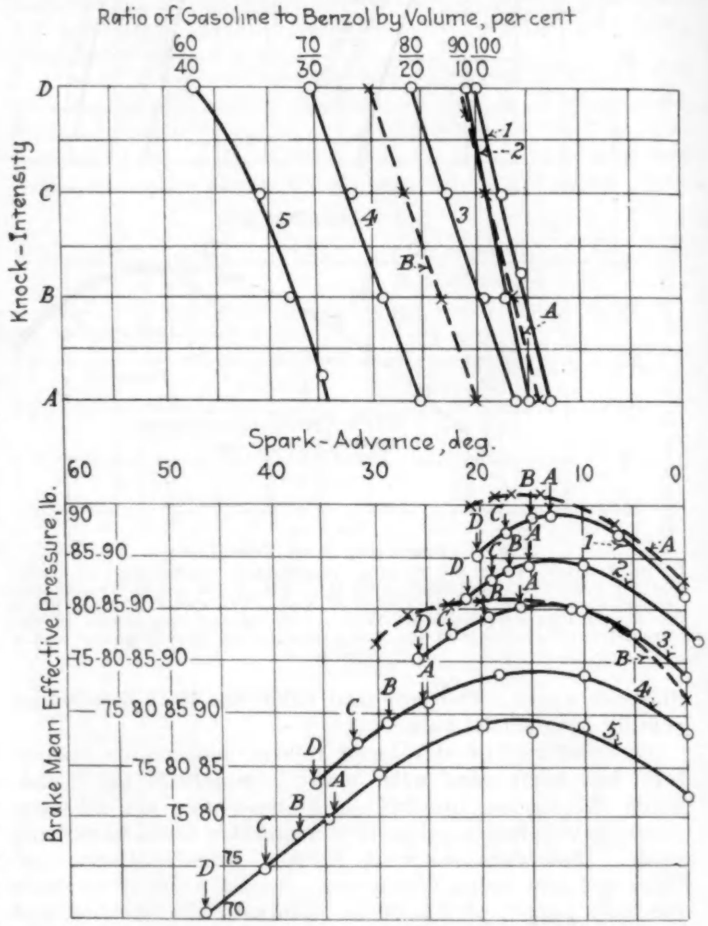


FIG. 7—SECOND SERIES OF GASOLINE AND BENZOL MIXTURES
The Results from Tests Similar to Those of Fig. 6 Are Presented. The Distillation Characteristics of These Fuels Are Shown in Fig. 14

versus 20-24. This indicates the actual spark-advance for *B* and *C* knocks. The values should be taken from the curve, rather than from the data sheet. This method of evaluating has the advantage of indicating the slope of the line, which seems to vary for different fuels.

Of the foregoing variation in expressing the *P*-and-*R* Index, the value based on the areas with the zero to 60-deg. area as 100 has been used for the single number-value, while the double valuation of the actual spark-advance at *B* and *C* intensities has been selected for a more comprehensive value. Either method has a special application when a standard of fuel or performance is specified. The *A*, *B*, *C*, and *D* to zero spark-advance area of the standard fuel can be used as the 100-per cent value, or the arithmetical mean of the double spark-advance figures can be called 100 per cent. With this method, the values over 100 are better than the standard, and values less than 100 are greater knockers than the standard fuel or engine. The method of areas is designated as *P*-and-*R* Index *A* and the mean value of *B* and *C* spark-advances in degrees is designated in this paper as *P*-and-*R* Index "*B*/*C* Sp. Ad."

It is noted that the lines become steeper for fuels that are bad knockers. Also, some fuels have the *A*, *B*, *C*, and *D* versus spark-advance lines straight, and some fuels curve to the right or to the left. The fuel that will produce satisfactory operation in the engine being

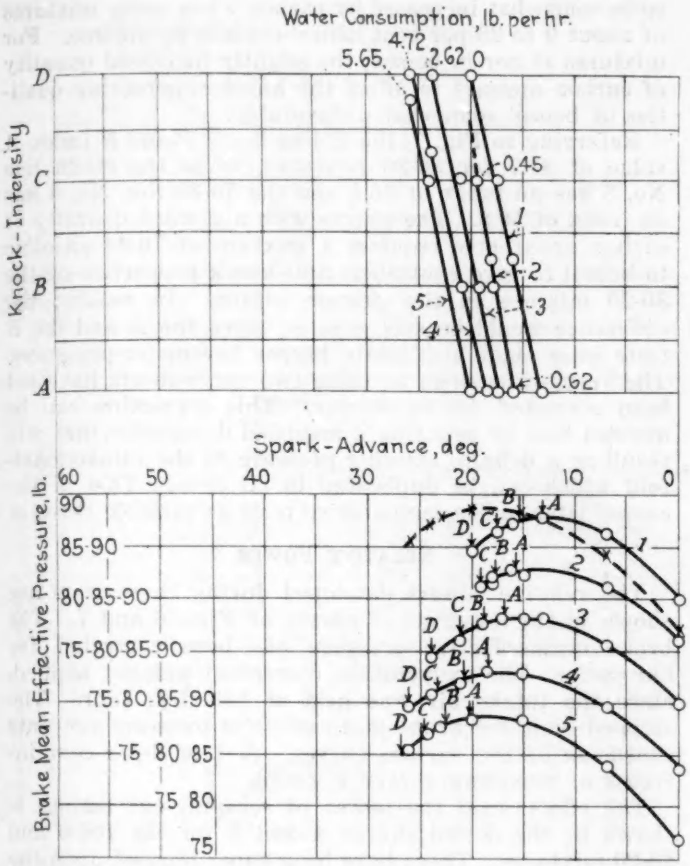


FIG. 8—GASOLINE AND WATER MIXTURES
This Chart Illustrates the Effect of Water When Admitted to the Intake-Manifold of the Test-Engine Just Above the Throttle

tested and under the particular conditions of test will not necessarily produce quiet operation for other engines unless the two combustion-chambers have equal anti-knock characteristics. However, it is believed that by selecting a fuel of known performance in this engine and using the same fuel in a second engine, a direct comparison of the comparative anti-knock merits of the engines can be made. From considerable experience with this method of test, it is believed that the difference between cast-iron pistons and various types of aluminum piston can be differentiated and evaluated with regard to the knocking characteristics.

OTHER METHODS OF EVALUATING KNOCKING CHARACTERISTICS

Another obvious way of using this method of testing to compare the knock-intensities of fuels, fuel dopes, or combustion-chamber shapes and conditions is to inspect the brake mean-effective pressure versus spark-advance lines. The location of the arrows A, B, C, and D on these lines with respect to the peak of the brake mean-effective-pressure curve furnished a definite insight into the knock or anti-knock characteristics. The location of the left end of the brake mean-effective-pressure line and its relation to the maximum value furnishes a further index to the fuel or engine characteristics. The numerical valuation may be the maximum brake mean-effective pressure divided by the end brake mean-effective pressure or the loss in brake mean-effective pressure at the end-point as compared to the maximum. Combination index-values incorporating both spark-advance and power data have been considered, but it appears that the P-and-R Index A and the P-and-R Index "B/C Sp. Ad." seems to be most practicable at present. Representative data are presented in the subsequent paragraphs.

ETHYL-FLUID ADMIXTURES

Fig. 5 shows the results of using raw gasoline and various increasing amounts of ethyl-fluid. The quantities of "lead" in the various series were 2, 4, 6, and 8 cc. per gal. These data are largely self-explanatory and have been compared to the tests with other anti-knock agencies on the summary curves in Figs. 17 and 18. The comparison is on the basis of P-and-R Index A and of P-and-R Index "B/C Sp. Ad." respectively. The comparison is for purposes of illustration and cannot be taken as a direct evaluation, since no corrections have been made for varying quantities of carbon in the engine or for variations in barometric pressure. The method of testing is sufficiently sensitive to differentiate small differences in these two factors.

GASOLINE-BENZOL MIXTURES

The curves in Figs. 6 and 7 represent results obtained from two series of tests made with various mixtures of a commercial gasoline and a benzol. The distillation characteristics of these fuels are shown in Fig. 14. The benzol S was used in the dynamometer tests and its density variation with temperature is also shown on the

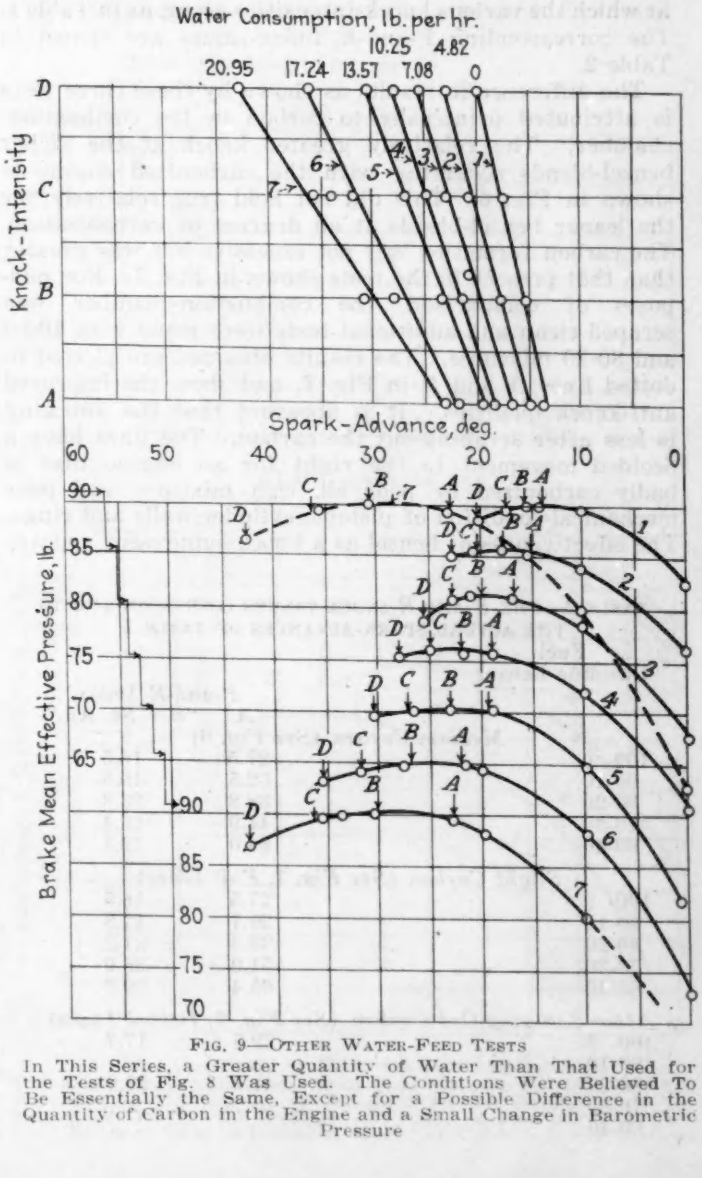


FIG. 9—OTHER WATER-FEED TESTS
In This Series, a Greater Quantity of Water Than That Used for the Tests of Fig. 8 Was Used. The Conditions Were Believed To Be Essentially the Same, Except for a Possible Difference in the Quantity of Carbon in the Engine and a Small Change in Barometric Pressure

TABLE 1—ACTUAL SPARK-ADVANCE AT WHICH THE VARIOUS KNOCK-INTENSITIES OCCUR

Fuel Gasoline-Benzol	Spark-Advance *A*	*B*	*C*	*D*
Medium Carbon (See Fig. 6)				
100- 0	13.0	15.5	17.0	20.0
90-10	16.0	18.0	20.5	23.0
80-20	18.0	21.5	25.0	29.0
70-30	19.5	24.0	28.5	33.5
60-40	24.0	29.5	35.5	41.0
Slight Carbon (See Fig. 7, Full Lines)				
100- 0	13.0	15.5	17.5	20.0
90-10	15.0	17.0	19.0	21.0
80-20	16.0	16.5	23.0	26.0
70-30	25.5	29.0	32.5	36.0
60-40	34.0	37.0	41.5	47.0
After Scraping-Out Carbon (See Fig. 7, Dotted Lines)				
100- 0	14.0	16.5	19.0	21.5
80-20	20.0	23.0	27.0	30.0

same curve sheet for reference. The benzol *A* was obtained from a different source and was used for comparative road-tests in a different engine than the one used in the electric cradle-dynamometer tests. The comparative anti-knock qualities of the benzol blends are shown directly in the upper set of curves in Figs. 6 and 7 and can be compared by tabulating the actual spark-advance at which the various knock-intensities occur, as in Table 1. The corresponding *P*-and-*R* Index-values are shown in Table 2.

The difference in results as shown by these three tests is attributed principally to carbon in the combustion-chamber. The relatively greater knock at the richer benzol-blends occurring with the carbonized engine is shown in Fig. 6. This did not hold true relatively for the leaner benzol-blends at all degrees of carbonization. The carbon formation was not excessive but was greater than that present in the tests shown in Fig. 7. For purposes of comparison, the combustion-chamber was scraped clean and additional tests were made with 100-0 and 80-20 mixtures. The results obtained are plotted in dotted lines *A* and *B* in Fig. 7, and show the improved anti-knock qualities. It is apparent that the knocking is less after scraping-out the carbon. The lines have a decided movement to the right for an engine that is badly carbonized by poor oil, rich mixtures and poor mechanical-condition of pistons, cylinder-walls and rings. The effectiveness of benzol as a knock-suppressor appears to be somewhat increased by carbon when using mixtures of about 0 to 25-per cent benzol-content by volume. For mixtures richer in benzol, the slightly increased quantity of carbon appears to affect the knock-suppressing qualities of benzol somewhat unfavorably.

TABLE 2—THE *P*-AND-*R* INDEX-VALUES CORRESPONDING TO THE ACTUAL SPARK-ADVANCES OF TABLE 1

Fuel Gasoline-Benzol	*P*-and-*R* Index *A*	"*B/C* Sp. Ad."
Medium Carbon (See Fig. 6)		
100- 0	27.5	16.5
90-10	32.5	19.5
80-20	38.8	23.3
70-30	44.0	26.4
60-40	54.0	32.5
Slight Carbon (See Fig. 7, Full Lines)		
100- 0	27.5	16.5
90-10	29.7	17.8
80-20	35.3	21.2
70-30	51.0	36.0
60-40	65.4	39.2
After Scraping-Out Carbon (See Fig. 7, Dotted Lines)		
100- 0	29.5	17.7
90-10	...	...
80-20	41.7	25.0
70-30	...	...
60-40	...	...

Referring to Fig. 7, the *B* line has a *P*-and-*R* Index *A* value of 41.7 for 80-20 mixtures, while the 80-20 line No. 3 has an index of 35.8 and the 70-30 line No. 4 has an index of 50.8. The engine with a greater quantity of carbon apparently requires a mixture of 76-24 gasoline to benzol to give equivalent anti-knock properties of the 80-20 mixture in the cleaner engine. In reality, the difference would be still greater, since the *A* and the *B* tests were made at slightly higher barometer-pressures. The knock-intensities on these two curve-sheets have not been corrected for barometer. This correction can be avoided best by selecting a manifold depression that will result in a definite absolute-pressure in the intake-manifold which can be duplicated in all tests. This is discussed later under comparative tests at variable throttle.

Relative Power

The relative powers developed during these tests are shown in the lower set of curves of Figs. 6 and 7. The brake mean-effective pressure has been corrected for barometer. The temperature correction was not applied, since the intake air was held at 160 deg. fahr. The stepped scale for brake mean-effective pressure prevents confusion of the various curves. A 1 or 2-per cent increase of maximum power is noted.

The effect upon the power of scraping-out carbon is shown by the dotted curves *A* and *B* for the 100-0 and 80-20 mixtures. These have been superimposed upon the scales used for curves 1 and 3 of corresponding mixtures when used in a slightly carbonized engine. The power increase is about 2 per cent for the 80-20 mixture when comparing the clean engine with the slightly carbonized engine. The effect of benzol on the power is apparently different in the two cases. In the carbonized engine, the use of benzol sometimes showed a slight increase of power, but this does not seem true in the case of the clean engine. These deductions are based on the conditions of test and may not necessarily be applied to other conditions.

A re-plot of the spark-advance versus maximum power showed the increase in spark-advance for the increasing benzol-content. The time required to burn the various mixtures completely appears to be noticeably greater in the case of those richer in benzol. This increase amounts to about 3 deg. of crankshaft travel at 1000 r.p.m. when changing from raw gasoline to a 60-40 mixture of gasoline and benzol.

Gasoline-Water Mixtures

Water has long been used as a knock-suppressor, especially in the larger kerosene-engines. The effect of water when admitted to the intake-manifold of the test-engine just above the throttle is shown in Fig. 8. The quantities varied from 0 to 5.65 lb. per hr., as the maximum. The latter represents about 41 per cent of the gasoline flow. The first 0.5 lb. per hr. of water-flow evidently is the most effective in suppressing the knock, although successive increments of water-flow all increased the index values.

Possibly the first small increment of water-feed may be more effective than is indicated by the curves. The smaller quantities such as are represented by the water content of saturated air at room temperatures have not been investigated, since all these tests have been made by the direct introduction of water to the manifold in

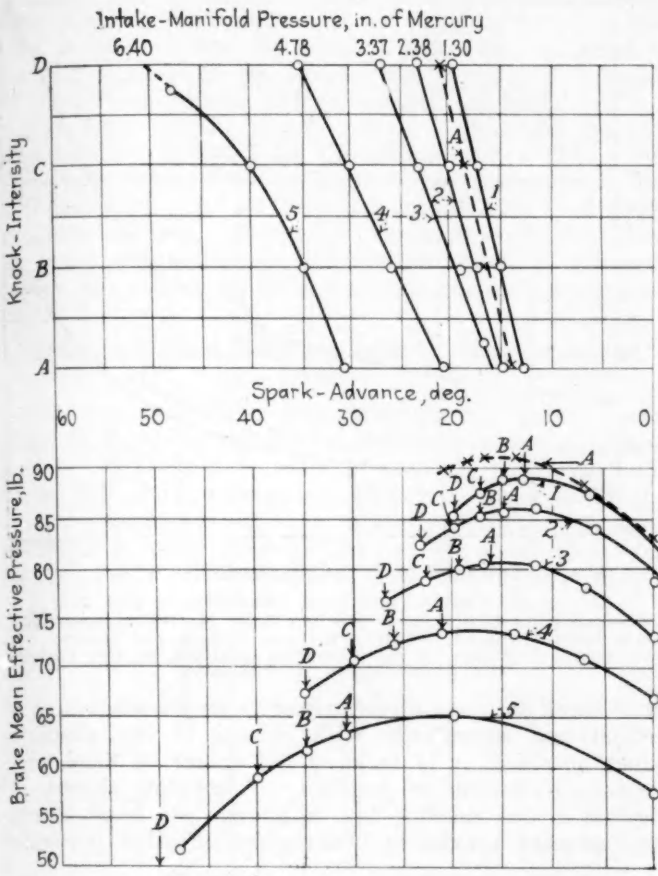


FIG. 10—TESTS MADE AT DIFFERENT THROTTLE-POSITIONS
The Tests Were Made at Wide-Open Throttle and at Partly Closed Throttle. They Serve To Give an Insight into the Application of This Fuel-Testing Method To the Effects of Altitude, Compression and Part Load

larger quantities. It was not ascertained whether complete saturation of the air with water vapor occurred. The water obviously had an influence on the quantity of dry air in the mixture due to its partial or 100-per cent vapor-pressure at the particular manifold temperatures. However, this study was beyond the scope of this work, although it may have a direct bearing on the results obtained.

Fig. 9 shows a series of water-feed tests made with a greater quantity of water. The conditions of tests were believed to be essentially the same as those shown in Fig. 8, except for a possible difference in the quantity of carbon in the engine and a small change in barometric pressure. Inspection of the spark-advance as an arbitrary index to the rate of burning shows that the spark-advance was increased about 15 deg. at 1000 r.p.m. while the engine developed about equal maximum-power at the respective operating-conditions of raw gasoline and raw gasoline plus 150 per cent by weight of water in terms of gasoline-flow. This spark-advance change corresponds to 0.0025 sec. For comparison, curve 7 has been shown in dotted lines on the same brake mean-effective-pressure scale as has been used for the raw-gasoline curve, No. 1. The relation of the arrows *A*, *B*, *C*, and *D* to the peak of the brake mean-effective-pressure curve furnishes an insight into cylinder actions. These should be compared to other tests as reported.

EFFECTS OF ALTITUDE, COMPRESSION OR PART THROTTLE

The tests shown in Fig. 10 were made at wide-open throttle and at partly closed throttle. They will serve to give an insight into the application of this testing method upon the effects of altitude, compression or part load. The tests are shown in full lines, curves 1, 2, 3, 4, and 5, and were made with a slightly carbonized engine. The dotted line *A* shows the effects of scraping the combustion-chamber. It represents wide-open-throttle conditions and is comparable to curve No. 1. The net gains for the power comparison are believed to be truly representative, since the brake mean-effective pressure has been corrected for barometric pressure; that is, with intake air-temperature constant. The net gain on the *P*-and-*R* Index *A* is from 26.7 and 29.2. This is uncorrected for barometer and is less than the corrected figures would show, since the *A* tests were made at slightly higher barometer than the curve-1 tests; therefore, the gain from scraping-out carbon would be slightly more than is indicated. This gain is not a direct function of the absolute pressure, but it can be so assumed for slight variation of barometer. For the conditions, it amounts to about 3.0 on the *P*-and-*R* Index *A* per inch of mercury. The relative figures as revised are 26.7 and 30.7, being for a slightly carbonized and for a clean engine respectively. The corresponding maximum power-gain is about 2 per cent with the change of spark-advance from 12.5 to 15.0 deg. early. The particular carbon-formation corresponded to a change in spark-advance for maximum power of about 3 deg. at 1000 r.p.m., or 0.0005 sec. In this comparison, as in others, it is well to note the position of the arrows *A*, *B*, *C*, and

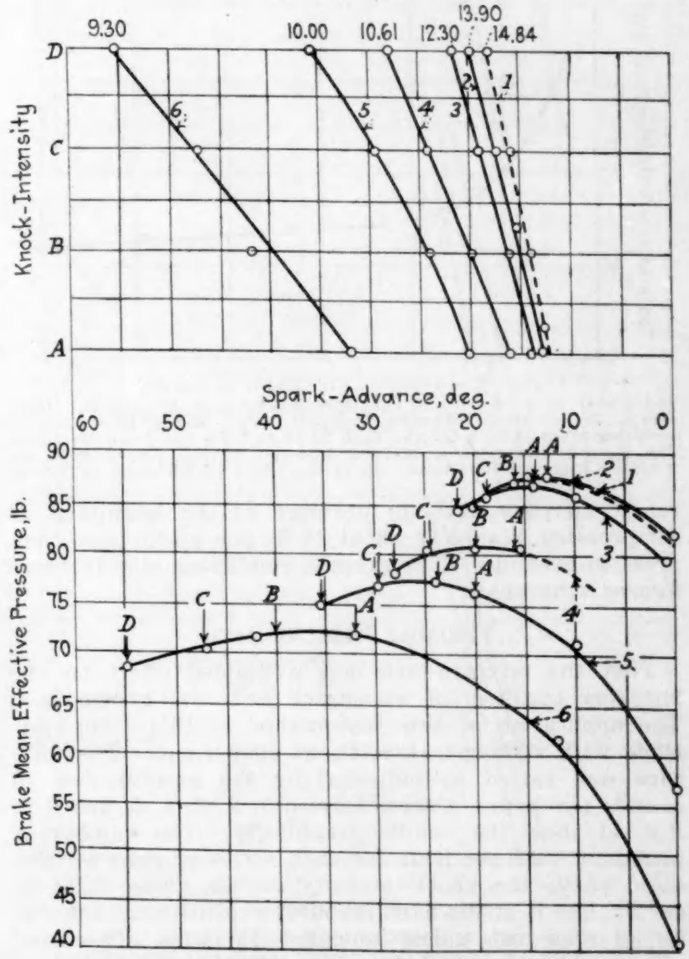


FIG. 11—STUDY OF VARIABLE MIXTURE-RATIO
The Study Was Made with Wide-Open Throttle at 1000 R.P.M. The Mixture Was Varied as Indicated by the Gasoline-Flow in Pounds per Hour. The Number of Pounds of Fuel per Hour for Each Series of Runs Is Indicated above the Knock-Intensity Curves

D, as related to the peak of the brake mean-effective-pressure curve.

The intake-manifold depressions corresponding to the various part-throttle tests are indicated on the curve sheet. The 1.3 in. of mercury corresponds to wide-open throttle. The mixture-ratios were not determined for these tests, but it is believed that they were fairly constant and that the results show the effect of variable throttle upon the knocking qualities of an engine under fairly uniform mixture-ratios. The highest intake-manifold depression shown is 6.4 in. of mercury and corresponds to about 5000-ft. altitude, neglecting exhaust conditions that do not simulate altitude conditions. The highest intake-manifold depression shown as 6.4 in. of mercury corresponds to a computed value of about 67 lb. per sq. in. gage compression-pressure using $n = 1.3$ and an absolute initial pressure at the beginning of compression of 23 in. of mercury. Computation, on the basis of 28

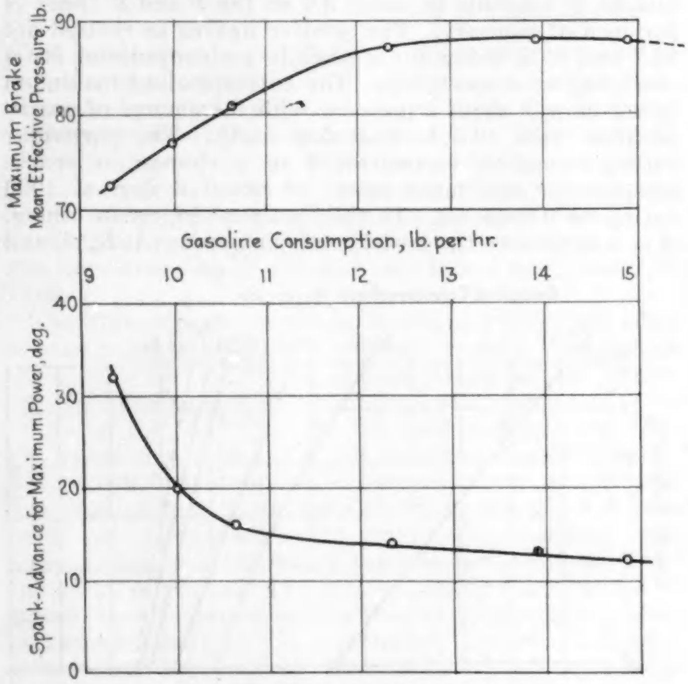


FIG. 12—APPROXIMATE MIXTURE-RATIOS
The Chart Is a Re-Plot of the Gasoline-Flow in Pounds per Hour versus Brake Mean-Effective Pressure. The Range Is Estimated as Being from 11 to 1 for the Rich to 18 to 1 for the Lean Mixtures. The Results Indicated a Marked Increase of the Knock with Increasing Richness of Mixture up to the Limit of Richness as Tested

in. of mercury absolute pressure at the beginning of compression, results in about 85 lb. per sq. in. gage compression-pressure. The exhaust conditions modify these figures somewhat.

VARIABLE MIXTURE-RATIO

That the mixture-ratio has a decided effect on the knocking qualities of an engine is a well-known fact. The application of this test-method to this study was made with wide-open throttle at 1000 r.p.m. The mixture was varied as indicated by the gasoline-flow in pounds per hour. Curves labeled 1, 2, 3, 4, 5, and 6 in Fig. 11 show the results graphically. The number of pounds of fuel per hour for each series of runs is indicated above the knock-intensity curves. The 13.90 lb. per hr. line is at the fixed carbureter-adjustment selected for all other tests unless indicated otherwise. This fixed adjustment was selected to simplify the test-procedure and necessarily had some disadvantages. In the case of benzol-mixture tests, to use a fixed adjustment for the raw gasoline and various blends is obviously incorrect.

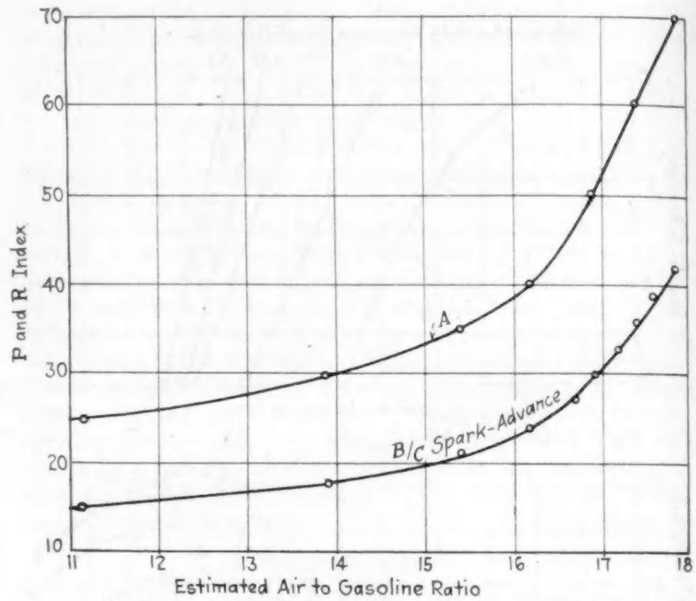


FIG. 13—RE-PLOT OF THE DATA PRESENTED IN FIG. 11
The *P*-and-*R* Indices *A* and "*B/C* Sp. Ad." for the Various Air-to-Gas Ratios from 11 to 1 Rich to 18 to 1 Lean Are Shown. A Very Striking Change in the Knocking Qualities of the Various Mixture-Strengths Is Noticeable

Since these data are given primarily as descriptive of a method and secondarily with regard to the absolute values obtained, it is believed the choice of fixed carbureter-adjustment is justified. A re-plot, shown in Fig. 12, of the gasoline-flow in pounds per hour versus the corrected maximum brake mean-effective pressure

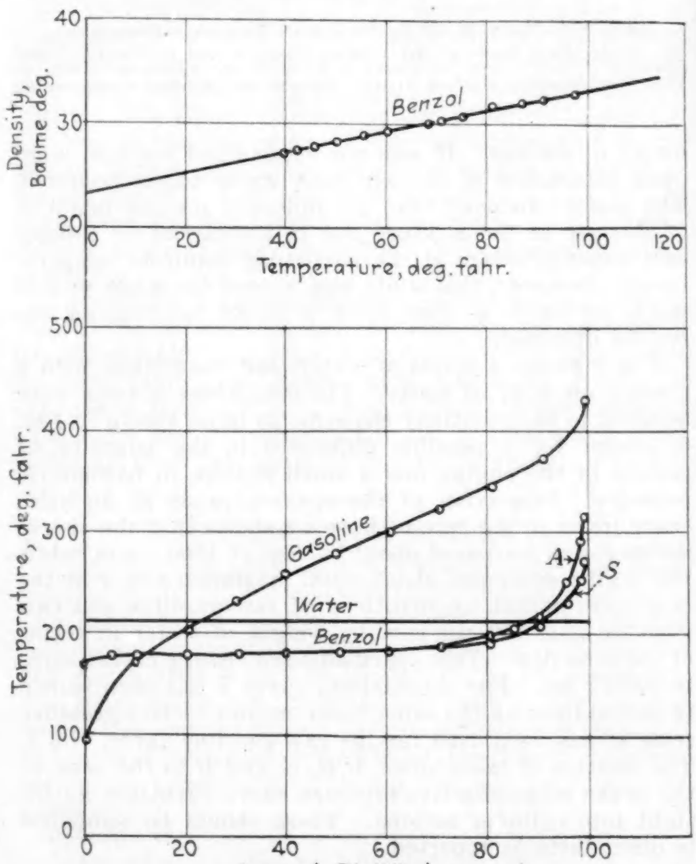


FIG. 14—DISTILLATION CHARACTERISTICS
The Fractional Distillation-Characteristics of the Fuel and the Benzol Are Depicted. The Boiling-Point of Water Has Been Added for Comparative Purposes and the Variation of the Benzol Density with Temperature Has Also Been Included for Reference

will serve to indicate the approximate mixture-ratios. The range is estimated as being from 11 to 1 for the rich to 18 to 1 for the lean. The results indicated a marked increase of the knock with increasing richness of mixture up to the limit of richness as tested.

The limits on the *P*-and-*R* Index *A* are 72.8 for the lean mixture and 25.3 for the rich mixture. These results were obtained with a small carbon-formation in the cylinder, and may be modified considerably for clean engine-conditions. The power varied from 87.8 to 72.2 lb. brake mean-effective pressure, corrected, for the extreme rich to lean conditions. The latter is 82.2 per cent of the maximum.

Spark-Advance Requirements in Mixture-Ratio Tests

The re-plot of these data shown in Fig. 12, has been made to show the spark-advance required for maximum power. Mixture-ratio tests made with fixed spark-advance will show different results from those using the best spark-advance for each mixture condition. A comparison of using fixed spark or variable spark for mixture-ratio runs shows that, at a 13-deg. fixed spark-

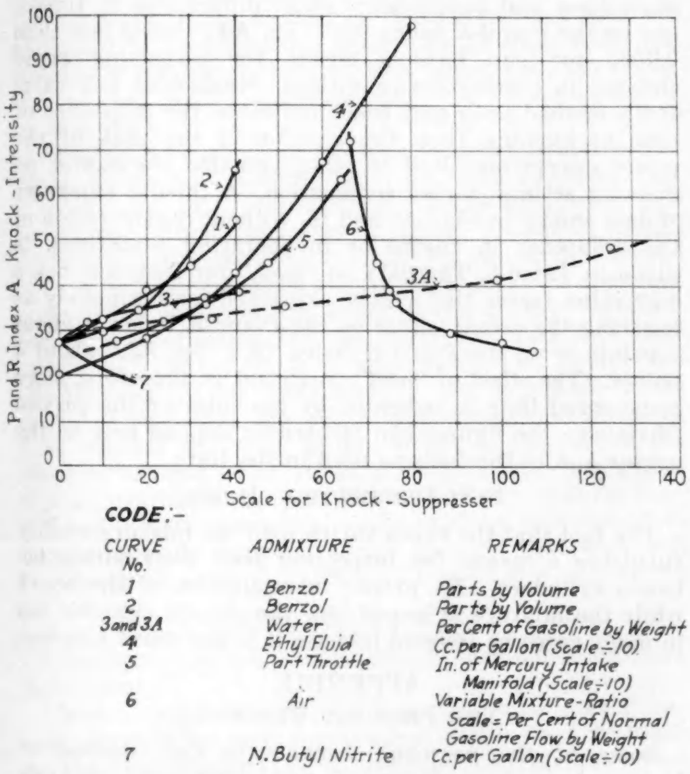


Fig. 15—Summary of Tests

The Results of the Various Tests Are Presented and Show Comparative Values of *P*-and-*R* Index *A*. They Are Not Directly Comparative, Since They Were Obtained under Slightly Different Engine-Conditions. Table 3 Gives a Tabular Summary

advance, the best power is obtained at 0.680 lb. of fuel per b.hp. per hr., and the best thermal-efficiency at 0.583 lb. of fuel per b.hp. per hr., being 22.45 per cent at an estimated mixture-ratio of 15.6 to 1.0.

The corresponding data for spark-advance varied to give maximum power for each mixture-ratio is 0.680 lb. of fuel per b.hp. per hr. for maximum power and 0.557 lb. of fuel per b.hp. per hr. for best thermal-efficiency, being 23.3 per cent at an estimated mixture-ratio of 18 to 1.

The approximate decreases of power from the maximum to that of best thermal-efficiencies for these two conditions are 9.0 per cent and 17.9 per cent respectively.

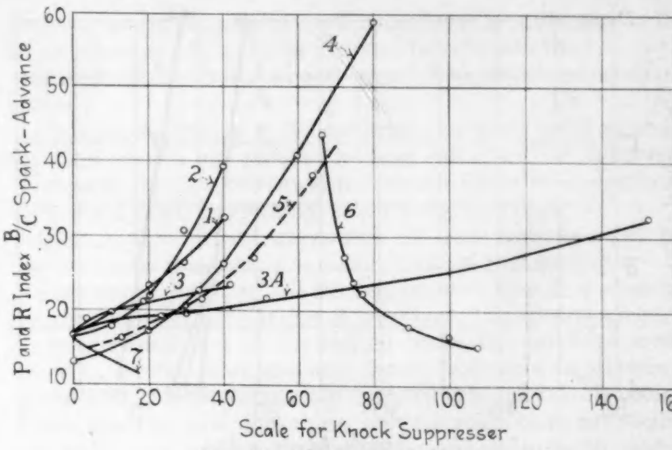


Fig. 16—Summary of Tests

The Results of the Various Tests Are Depicted and Show Comparative Values of *P*-and-*R* Index "*B/C* Sp. Ad." A Tabular Summary Appears in Table 3

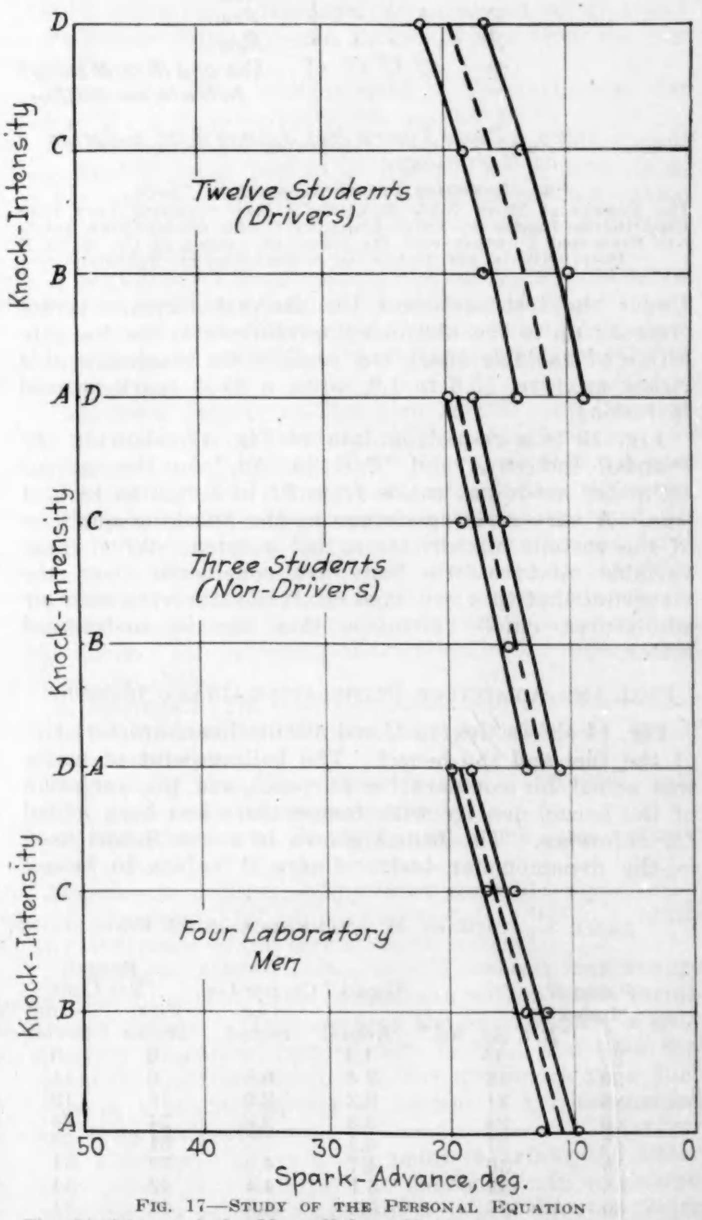


Fig. 17—Study of the Personal Equation

The Limiting and the Mean Values Obtained by 12 Students, All of Whom Had Driven Cars, Are Shown in the Upper Group and Those Obtained by 3 Non-Driver Students, Are Indicated in the Center Group. The Lowest Curves Show the Variation in the Results for Four Laboratory Men Experienced in Dynomometer Work

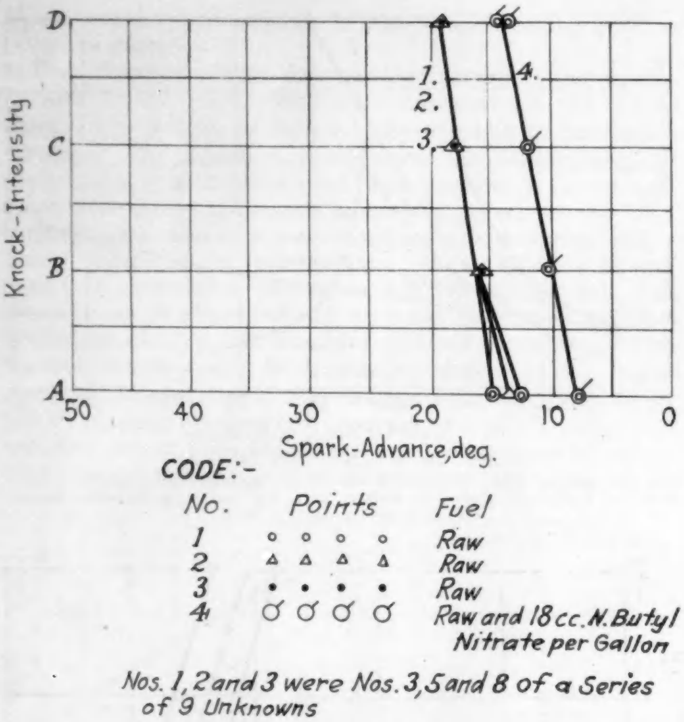


FIG. 18—OTHER PERSONAL-EQUATION TESTS
The Results of Tests While Selecting a Raw Gasoline That Was Used in the Engine at Three Unknown Times during Nine Trials Are Presented Together with the Effect of Adding 18 Cc. of an *N* Butyl Nitrite per Gallon of a Commercial Gasoline

Under the test-conditions the thermal-efficiency is increasing up to the 18.0 to 1.0 mixture-ratio for the condition of variable spark but reaches the maximum at a richer mixture, 15.6 to 1.0, when a fixed spark is used in testing.

Fig. 13 is a re-plot of data in Fig. 11, showing the *P*-and-*R* Indices *A* and "*B*/*C* Sp. Ad." for the various estimated air-to-gas ratios from 11 to 1 rich to 18 to 1 lean. A very striking change in the knocking qualities of the various mixture-strengths is noted. When these variable mixture-ratio tests are considered from the viewpoint that they are fixed mixture-ratio tests with air admixtures, chiefly nitrogen, they can be understood better.

FUEL AND ADMIXTURE DISTILLATION-CHARACTERISTICS

Fig. 14 shows the fractional distillation-characteristics of the fuel and the benzol. The boiling-point of water was added for comparative purposes and the variation of the benzol density with temperature has been added for reference. The benzol shown in curve *S* was used in the dynamometer tests. Curve *A* refers to benzol used in some comparative road-tests and shows somewhat different characteristics.

SUMMARY

The results of the various tests are depicted in Fig. 15, and show computed values of *P*-and-*R* Index *A*. These results are not directly comparative since they were obtained under slightly different engine-conditions. The chief modifying factor is believed to be carbon, so far as knock and power are concerned. The particular barometric-pressures occurring during the tests also modify the knock characteristics as given. Some insight may be had, however, into the relative values of the various suppressers and the effect of carbon, altitude, compression, and mixture-ratio.

Fig. 16 shows the same results when using the *P*-and-*R* Index "*B*/*C* Sp. Ad." While the two summary-graphs are believed to be self-explanatory with respect to relative anti-knock values and power, it is further believed that they may show characteristics which will substantiate or refute some of the theories of detonation and thus narrow the subject to afford a better understanding. Since the spark-advance and, hence, the index values, show time and particularly small differences in time—one on the *P*-and-*R* Index "*B*/*C* Sp. Ad.," being less than 0.0002 sec.—we have a means for inspecting rapid changes in combustion conditions. Neglecting any value of the method as an anti-knock indicator, the inspection of time of burning from the location of the peak of the power curves may lead to other valuable disclosures on cylinder actions during combustion. A tabular summary of data shown in Figs. 15 and 16, without consideration of the difference in engine or in operating conditions, is given in Table 3. The data on "lead," for instance, has a correction factor that can be expressed approximately as lowering the actual values on the *P*-and-*R* Index *A* about 7 points or on the *P*-and-*R* Index "*B*/*C* Sp. Ad." about 4 points. The effect of "lead" treatment is, therefore, more pronounced than is indicated by the table or the curves. Obviously, the figures can be strictly applied only to the engine and to the fuels as used in the tests.

FUEL-DISTRIBUTION INDEX

The fact that the knock varies with the mixture quality furnishes a means for inspecting poor distribution between cylinders. By proper manipulation of the spark while the mixture is leaned out, the richest cylinder can in many cases be isolated because it is the worst knocker.

APPENDIX

THE PERSONAL ELEMENT

Some of the personal elements in this method of testing have been inspected and reasonably accurate

TABLE 3—SUMMARY OF ANTI-KNOCK INDEX EVALUATIONS, DATA NOT STRICTLY COMPARATIVE (See Figs. 15 and 16)

P-and-*R* Index		"Lead," Cc. per Gal.		Benzol, Per Cent		Water, Percentage of Gas		Inlet-Manifold Pressure, Absolute, In.	Mixture-Ratio	
A	"*B*/*C* Sp. Ad."	Actual	Corrected	First Series	Second Series	First	Second		Gas Per Hour, Lb.	Estimated Ratio of Air to Gas
25	15	1.4	..	0	0	0	0	29.4	15.00	11.1
30	18	2.4	0.8	6	11	3.5	8	27.9	12.00	13.9
35	21	3.3	2.0	16	19	22.0	47	26.7	10.80	15.4
40	24	3.8	2.8	24	24	52.0	87	25.8	10.30	16.2
45	27	4.2	3.5	31	27	...	116	25.1	10.00	16.7
50	30	4.7	4.0	37	31	...	134	24.6	9.86	16.9
55	33	5.1	4.4	42	34	...	152	24.2	9.73	17.2
60	36	5.5	4.9	46	37	...	...	23.7	9.60	17.4
65	39	5.8	5.3	..	40	...	...	23.3	9.47	17.6
70	42	6.2	5.7	..	42	...	...	23.0	9.34	17.9
80	48	6.8	6.3	..	..	...	...	...	...	...
90	54	7.5	7.0	..	..	...	...	...	...	...
100	60	8.2	7.7	..	..	...	...	...	...	...

check-results have been obtained by operators using fuels that were not previously identified. While it is recognized that the personal element is present, the work showed much greater uniformity than was believed possible during the earlier stages of the test-method development. The use of a standard fuel facilitates the establishment of the code letter for the various knock-intensities or furnishes a standard for comparison.

In addition to checking on fuels unknown to the dynamometer operator, a scrutiny of the test-results herein given is believed to indicate that they, themselves, prove the value of the method.

Fig. 17 shows a further study of the personal equation. The upper series of lines shows the limiting and the mean values obtained by 12 students at Armour Institute of Technology, the latter curve being dotted. All these men had driven cars. Three non-driver students showed a smaller variation, as indicated in the center group of curves. These 15 men were each shown by example the knock desired for *A*, *B*, *C*, and *D* intensity. This took approximately 2 min. Each man then set the spark-advance according to his own version of the instructions. The lowest group of curves in Fig. 17 shows the variation in the results for four laboratory men experienced in dynamometer work. In all these tests the speed was not rigidly held at 1000 r.p.m. and, therefore, the expected results should be better than those indicated by this check.

An additional study of my own personal equation was made, using raw gasoline and the same gasoline with 2 cc. per gal. of *n* butyl nitrite. These fuels were differentiated from unknowns in three successive trials. Additional tests using up to 18 cc. per gal. of this knock-inducer indicated that it had an average knock-inducing value of 0.3 points on the *P*-and-*R* Index "*B*/*C* Sp. Ad." per cubic centimeter for the particular fuel and test-conditions. The first 2 cc. apparently had double the effectiveness of the remainder of the maximum treatment. These data are shown graphically as line 7 in Figs. 15 and 16. Fig. 18, curve No. 4, also shows the effect of adding 18 cc. of an *n* butyl nitrite per gallon of a commercial gasoline. The latter figure, curves Nos. 1, 2 and 3, also shows the results of these personal-equation tests while selecting a raw gasoline that was used in the engine at three unknown times during nine trials.

THE DISCUSSION

QUESTION:—Is the fuel-weighing machine a standard instrument?

PROF. DANIEL ROESCH:—Not in the sense that it has been adopted by any engineering society, but it fulfils all the requirements of a standard instrument. This machine is very rapid, is always ready for a test at any time and greatly facilitates the accurate determination of fuel consumption by weight.

QUESTION:—At what point in the mixture do the loading-up effects diminish?

PROFESSOR ROESCH:—If the engine can be run at the 15 to 1 ratio, that is, at about 11 lb. of gasoline per hr. as in Fig. 12, it would be very desirable, but a noticeable loss in power occurs when you get that condition.

Mixture-ratios are always very interesting and instructive. If the engine can be run just underneath the peak, that is, at the point corresponding to 12.0 or 12.5 lb. of gasoline per hr. as in Fig. 12, one probably will have about as good conditions as an experienced operator of cars can get. If the hot-spotting and the temperature of the engine will permit it, running at the theoretical mixture is desirable. Some power will be lost when that is done and car-owners probably will object to it. Besides losing some power, considerable difficulty will be experienced in getting started in cold weather.

QUESTION:—About where would the effect of alcohol enter?

PROFESSOR ROESCH:—I have made no tests with alcohol for this series, but alcohol is very effective. A mixture of alcohol, benzol and gasoline would likewise constitute very good fuel, neglecting price consideration.

QUESTION:—What percentage of lead does one get in the ordinary ethyl-fluid solution sold on the market?

PROFESSOR ROESCH:—I do not know. One can readily determine what proportion it requires. It depends largely on how effective it is desired to make the mixture with respect to the compression used, combustion-chamber shape and carbon formation permissible before cleaning. Some engines are operating on the road that are built for 60-lb. per sq. in. maximum compression with wide-open throttle, while some are built for 85 and 90 lb. per sq. in. and higher. On a basis of compression-ratios, we are getting up around 4.75 and higher.

B. S. PFEIFFER:—Was specially analyzed water used?

PROFESSOR ROESCH:—No, the water was from the city water-supply.

QUESTION:—Was readjustment of the carbureter for the addition of water taken into account?

PROFESSOR ROESCH:—No, the carbureter adjustment was fixed at about 13.9 lb. of fuel per hr. at 1000 r.p.m. and at wide-open throttle I doubt that the air-flow varied very much with the increased water-flow. We did not use an air-meter in these tests.

A MEMBER:—I have made numerous tests running on kerosene with water added. Invariably, I found that a rich mixture of kerosene would stop a knock; but, upon the addition of water, we always reduced the quantity of kerosene.

PROFESSOR ROESCH:—The rich mixture of kerosene that is in excess of that actually needed probably was acting as an anti-knock agent. The same thing is true when running with rich mixtures of gasoline. However, that might easily cause trouble if tried on the road, because the carbureter has a gasoline opening not large enough to allow excessively rich mixtures; so, the choke is used to enrich the mixture. If the choke is used, the engine compression is reduced and that in itself reduces the knock. The metering characteristics are upset when using the choke.

A MEMBER:—The condition under which I was testing was not by choking; it was done entirely with an ordinary carbureter.

PROFESSOR ROESCH:—Then it was a straight anti-knock feature of the kerosene excess.

A MEMBER:—The straight anti-knock was entirely on the fuel feed to the engine.

PROFESSOR ROESCH:—Any inert gas will help.

A MEMBER:—In your various tests did you notice any difference in the formation of carbon?

PROFESSOR ROESCH:—No, we did not test long enough to determine that. We usually ran with a small formation of carbon. After scraping the engine clean, a small quantity of carbon formed very rapidly, and even that quantity could be detected in the anti-knock of a fuel; that is, a slight quantity of carbon is a knock-inducer and it is noticeable.

A MEMBER:—There is one point regarding the water-feed curve, if I interpret it correctly. In a straight gasoline you get the maximum torque at about a 12-deg. spark-advance and that corresponded about to knock-intensity *A*. You introduced water, say nearly 100 per cent and, at a 12-deg. spark-advance the engine lost considerable power, approximately 5 to 7 lb. per sq. in.

mean-effective pressure. Then you found, by advancing the spark up to 25 deg., that the mean-effective pressure came back but that still corresponded to knock intensity *A*. If you set the spark up to maximum power, you could do that; but you had the same knock-intensity you had before.

PROFESSOR ROESCH:—In that respect the water is entirely different from the benzol or the ethyl fluid. Knock-intensity *A* appears near the maximum power part of the torque curve for all the additions of water.

A MEMBER:—When water is injected, usually the fuel-flow has to be increased to hold the power.

PROFESSOR ROESCH:—The power was maintained just about the same for all water additions and I am sure the gasoline-flow was the same. I feel fairly sure the mixture of air to gasoline was about the same. A slight variation of the air-content exists as you advance the spark, due to the thermal conditions in the engine; that is, as the combustion-chamber becomes warmer, the volumetric efficiency drops.

QUESTION:—What is the action of the water in there?

PROFESSOR ROESCH:—I am not prepared to say. I think much water goes right through the engine when you are using so large a quantity. The water-carrying capacity of air increases rapidly with increase of temperatures.

QUESTION:—Does the water have a tendency to cool the mixture of gas?

PROFESSOR ROESCH:—Yes, and in that way it has a tendency to increase the volumetric efficiency. The cooling effect due to evaporation is considerable but, naturally, the time element is an important factor.

MOLDING-SAND

THE selection of sand should receive the most careful attention of the foundry manager, and, if the foundry is fortunate enough to possess one, the works chemist also. A molder may bestow due care on the making of a good mold in the matter of venting and ramming, but unless he has the right sand castings will be defective. In England molding sand is called "green sand," because the original sand used for molding came from Aylesbury and had a peculiar green tint due to the presence in it of silicate of iron and potassium. The Mansfield, South Staffordshire and Kidderminster sands are red, owing to the iron oxide they contain. Green sand is distinguished from other sands by the fact that, when lightly squeezed in a damp state, it retains its shape. This is due to the presence of certain bonding materials, of which clay or alumina silicate is the most common. Molding sand also contains silica, granite, feldspar, mica, quartz, soda, potash, lime, magnesia, and metallic oxides, but clay is the most important constituent.

Clay in contact with molten metal is burnt and gives up its combined water. Once it has given up this combined water, no amount of watering will restore its plasticity. Hence a certain quantity of new sand should be used on every mold. If this were neglected, the floor sand would soon get too weak to hold itself in the box parts. In spite, however, of new sand being added daily, large top parts of molds fall out in course of time when the box is turned over. Want of ramming is not the cause of the trouble; it lies in the fact that the floor sand has become too weak to hold itself together, and the sole remedy is to cast out of the shop many hundreds of loads and replace this by more new sand in the molds for a few weeks. The proper course is to keep the shop floor sand down to a predetermined level, and then the trouble of weak floor sand will not arise.

The essential requirements of good molding sand are:

(1) The sand of which the mold is formed must allow the free passage of air and gases generated at the moment of casting

(2) It must be capable of withstanding high temperatures without fusing

(3) It should be readily removable from the cold casting and leave a clean and smooth skin

(4) When rammed into shape, it should be firm and sufficiently compact to resist the pressure of the liquid metal

Excess of lime is disastrous because it makes the sand fusible. Metallic oxides also impair the refractory qualities of molding sand, while clay and bond must not be present in excess, because they destroy porosity. Moreover, clay burns at a much lower temperature than the melting-point of iron, and an excess would result in a very rough casting.

Sand should contain from 5 to 7 per cent of moisture, and, as it must be well mixed, it should never be used until it has been steeped for at least 12 hr. Where no mixing plant is installed, steeping the sand is often neglected, and it will pay to give this matter attention. If the sand is too wet, it will form excess gas or steam and cause the casting to blow. Unless it is well mixed, damp spots will occur, even though the molder uses every day the same quantities of water and sand. A rough but satisfactory test of dampness is to squeeze a ball of sand in the hands. If it clings or leaves the hand rough, it is too damp; if it crumbles it is too dry. In the choice of sand the design of the pattern ought also to be taken into consideration. For instance, for fine parts, such as sharp beads or fancy work, the sand must be strong. It must contain a high proportion of bond to resist the washing action of the metal. For a flat mold a weaker sand can be used.

In the choice of sieves and riddles, it should be remembered that these provide a first class means of mixing sand. To obtain a good surface on a casting, the sand, when sleeked, must make a polished surface without the aid of a superficial facing. This can only be obtained by putting the sand through a fine sieve. It must be borne in mind, however, that when the sand is sifted on the pattern the thickness must be kept at the minimum, because with sand of this grade it is possible for the mold to become impervious to the passage of gases.

Black sand, for making light castings, should be constituted approximately as follows:

Constituents	Per Cent
Silica	78.50
Alumina	4.75
Iron oxide	6.00
Lime	0.30

The percentage proportion of silica in molding sand should be approximately as follows:

Kind of Casting	Per Cent
Light Brass	80
Light Iron	82
Medium Iron	84
Heavy Iron	88
Steel	95

The impurities commonly found in sand are soda, potash and organic matter, but where these total less than 1 per cent they are not injurious. The essential feature of molding sand is the percentage proportion of silicate of alumina, present as raw clay, representing binding qualities. The higher the percentage of quartz grain or silica grain not in chemical composition with other minerals, the more refractory the sand. This is due to the fact that silica melts at about 1700 deg. cent. (3092 deg. fahr.) whereas iron melts at about 1300 deg. cent. (2372 deg. fahr.).—*Automobile Engineer* (London).

Common Troubles with Present Headlighting Equipment

By Alfred W. Devine[1]

Semi-Annual Meeting Paper

ABSTRACT

THE program of the Joint Steering Committee on Headlighting Research includes a survey by the author of present new-car head-lamp equipment. In his presentation of the results of this survey he states that the present system of headlighting control should be perfected to such an extent that the principles upon which it is based are given a practical application.

Main difficulties that have prevented attainment of the best results from the present system are inferior head-lamp equipment supplied with the automobile and improper use of it by the car-owner and operator. Attention should be given to such details of head-lamp construction as the use of non-ferrous lamp-socket tubes, the elimination of all unnecessary breaks in the line carrying the electric current, the definite location and secure installation of front glasses, the drainage of moisture, the proper construction of lamp doors, the use of suitable connectors, the use of proper reflector-retaining mechanisms that will hold the reflector securely and locate it definitely, better construction of lamp mountings and the supports to which they may be attached, accurate location of the beam-modifying device if no aiming adjustment is provided in a plane perpendicular to the reflector axis, simplification of the aiming and the focusing adjustments, and the construction of head-lamps such that the lamp fronts will be approximately vertical when properly adjusted.

Immediate attention should be given to variations from designed optical characteristics that result from variations in reflector contour and to improper location of the light-source; also, to a strengthening and other improvement of lamp mountings and the supports to which they may be attached.

IN general, it may be correctly stated, as the opinion of those men who have given the subject serious consideration, that the present motor-vehicle headlighting-situation can be improved considerably. Concerning the methods of making improvement, opinions vary from moderate changes in the present system to others that are radically different. Dissatisfaction has been found with and criticism made of the present system, and the general feeling that an improvement in conditions should be sought is significant of better conditions to come by reason of the interest and development that such dissatisfaction engenders.

Although not strictly within the scope of this paper I cannot let this opportunity pass without making a few general remarks. We hear considerable more or less unintelligent criticism from the public which is chiefly directed against glare from approaching cars. When such criticism is made, it generally will be found that the critic has not given sufficient attention to his own headlighting-equipment and its proper adjustment. That most of the criticism of the present system would be equally applicable to many others that have been proposed probably is true and in many of these proposed systems, other difficulties would be encountered which might be worse than the troubles that they overcome. Before any radical change is made in the system now in general use, very careful consideration should be given and suitable tests made to determine whether an actual improvement will result. The organization of the Joint Steering Committee of the Society and of the Illuminating Engineering Society on the subject of headlight research was a commendable step in the right direction. This Committee can be expected to serve as a balance between radicalism and conservatism and to exert a guiding influence in a proper study of the subject.

Practical Application Needed

The fact that considerable study is now being given to the problem and the possibility that a better system may yet be devised do not absolve us from the duty of perfecting the present system to such an extent that the principles upon which it is based shall be tested by a good practical application. The difficulties that have thus far prevented the best results from the system are inferior equipment supplied with the automobile and improper use of equipment by the car-owner and operator. The first difficulty is responsible to a considerable extent for the second. Equipment of good durable construction, free from every possible complication and with optical characteristics that are definitely good when such equipment is properly used, will more quickly bring the car-owner to a realization of what is desired and make him feel entirely dissatisfied with any other but the proper results from his equipment. An interest in his headlighting equipment will thus be fostered and enforcement will be made practicable.

It has seemed to me that the improvement of new-car equipment has been handicapped seriously in general by a lack of proper understanding of the problem by the men who determine the policies of the automobile-building companies. The engineer may design an equipment that will give satisfactory performance, but the chances are that he will not produce the design for such an equipment knowing that the purchasing agent and the policy of the company will make his effort futile. Some of the head-lamps in use today remind me of the nicely finished but flimsy metal toys that are sold for children's playthings. The head-lamp is not a toy, but it should be built to fulfill the use for which it is intended; it should not be considered as a minor detail to be handled as cheaply as possible. Cost is not the direct concern of the motor-vehicle administrator, but it may serve as an indication of flimsy construction. More drastic State-regulation is invited by the automobile-builders' failure to give this subject the attention it deserves. It ought to be handled by the car-builder as a safety matter and in such a way that further State-regulation is unnecessary. I refer to the car-builder in this problem because he is the one who is responsible for the headlighting equipment on his cars. The lamp manu-

[1] M.S.A.E.—Engineer in charge, equipment section, Registry of Motor Vehicles, Commonwealth of Massachusetts, Boston.

facturer may cut prices and may furnish a flimsy lamp but, if he does, it is either because the car-builder has not written proper specifications for lamp construction or is not holding the lamp manufacturer to those specifications.

The viewpoints of the average automotive electrical engineer and the State administrator are somewhat different because the former, if he gives the matter serious thought, is interested in producing a unit with which certain results *may* be obtained, and the latter is interested in seeing that certain desirable results are actually accomplished in practice.

It is my purpose in this paper to present some of the most common difficulties met by the enforcement official and to explain their causes. This is a matter that is having my immediate attention in a survey of present new-car head-lamp equipment that is being made as a part of the program of the Joint Steering Committee on Headlighting Research. The presentation of this paper to the Society results directly from a partial report of that survey made to the foregoing committee.

Method of Survey Described

Two inspectors, best fitted to do the work, were selected from the squad of equipment inspectors attached to the Registrar's office and assigned to make the required tests and investigations. Cars were taken in order of their total sales in this territory, eliminating temporarily those cars that use a complete approved head-lamp unit. A typical head-lamp on a new car was dismantled, examined and described so that future reference to the accumulated data might have a definite application. The construction details were noted and a comparison made with like or similar parts of the same kind or with other lamps that had been in service for a considerable period. From this comparison conclusions were drawn as to the durability, adjustability and simplicity of the lamp and the ease of replacement of its parts. Approved head-lamp adjusters and repairmen attached to the service-stations of each particular make of car were questioned in regard to the common troubles that they had found with the head-lamps.

About 25 new cars of each make were placed successively on a level headlight test-stand with the head-lamps 25 ft. from the test-screen. Then, the head-lamps were focused. The vertical beam-depth was measured in the center of the beam from each head-lamp, the determination of the beam-limits being made by one of the inspectors who stood behind the head-lamp and described the location of the beam-limits to the other inspector, who measured the depth of the beam on the wall. Location of the beam-limits was aided by a slight vertical rocking of the head-lamp by hand. These measurements of beam-depth were made with lenses installed and, in order that the most useful measurements might be made, the beam-deepening prisms on the lower part of one type of lens were covered while the measurements were made. This procedure eliminated a possible variable so that the results might be indicative of important variations in lenses, reflectors or positioning of the light-source. Attention also was given to the definition of upper cut-off, confinement of the beam within its apparent proper limits and the vertical disposition of the zone of maximum intensity. In a few cases measurements also were made of the diameter of the focused spot from lamps having the lenses removed to determine the cause of variations in beam-depth. In addition, tests are now being made to determine the time necessary to focus and aim the different head-lamps.

Criticism of Construction

The following constructional details were subject to criticism in the various head-lamps tested:

(1) Using a steel tube to guide the lamp sockets
(2) Using connectors that do not give a solid current-path
(3) Insecure methods of holding front glasses in place
(4) Provision should be made for the drainage of moisture condensing in the head-lamps
(5) Lamp-door construction
(6) Using a fiber washer in the connector socket
(7) Using reflector-retaining mechanisms that necessitated distortion of the reflector for the installation of the latter
(8) Design and strength of lamp mountings
(9) Downward tilting of head-lamps

The use of a steel tube to guide the lamp socket causes difficulty in focusing due to rapid corrosion of the tube, and particularly in cases where the steel tube projects through the back of the housing. Allowance is made sometimes for this corrosion, but this procedure is to be criticized freely because of the resultant inexact location of the incandescent lamp. If no clearance is allowed for corrosion it is found impossible to focus the lamp after a short period of service, unless the lamp is taken apart and the corroded surface is cleaned. In either case, the proper solution is the use of a well-designed non-ferrous tube or possibly the elimination of such a tube.

In the case of one of the cars examined, it was found that connectors were used which did not give a solid current-path. The failure to use sockets and connectors of the solid-current-path type causes unnecessary line-loss and consequent diminution of candlepower from the incandescent lamps. It should be realized that a variation of 1/4 volt from normal causes a loss of about 3 cp. After cars have been in service for a time, the corrosion of battery terminals and of fuse, switch, socket, and connector contacts and the loosening or corrosion in the grounded lamp-support may cause a very considerable drop in voltage. Therefore, all unnecessary breaks in the current-line should be avoided.

The use of light flimsy lens-retaining clips and the failure to provide a proper lens-locating clip to prevent rotation of the latter is not good practice.

Some cases were noted in which provision for the drainage of moisture condensing in the head-lamps was not made. If the condensation is permitted to remain inside the lamp housing, corrosion takes place much more rapidly than usual, particularly when an increase in outside temperature or heat from the incandescent lamp revaporizes this condensation and not only increases the rate of corrosion but also may cloud the inside of the cover glass, with a consequent reduction in illumination.

Considerable improvement can be made over the methods now in use for the construction of lamp doors. To remove or attach the door easily should be possible and the reflector should be sealed as well as possible against the elements when the door is attached. Slight distortion of a properly designed door should not interfere with its attachment to the lamp or with the sealing of the reflector. Sealing-braids fastened by adhesives did not seal reflectors properly after the doors were removed a few times. Generally, one removal of the door was sufficient to break the cord free from its seat and, thereafter, it was impossible to seal the reflector properly without resetting the sealing-braid carefully, which is a difficult operation for the average motorist.

The bayonet-joint method of holding doors in place has generally proved to be unsatisfactory on account of difficulty in some cases of installing and removing such doors without a special strap-wrench, due to the loss by breakage and distortion when insecurely held doors have loosened and fallen to the ground and because of the damage to the reflector seal from the rotational movement of the door. If not apparent on new lamps, these difficulties may become apparent after a period of service due to corrosion of the bayonet-lock seats, lamp-shells and steel springs; also because of breakage of flat bayonet-lock springs, the loss of spring tension, slight distortion of the door, and the loosening of the riveted parts of the lock. If doors of this type are used in connection with lamps constructed so that the reflector is pushed back against spring tension when the door is installed, the loosening or breakage of one or more of the bayonet locks may result in distortion of the beam by reason of the displacement of the reflector axis from the bulb axis, the improper sealing of the reflector or both.

Doors of the hook-on type should be designed so that the sealing gasket will not be broken, distorted or displaced when the door is applied. Most doors of this type thus far designed have these disadvantages to some extent. Little is to be gained by changing the design of the attaching mechanism of the door unless such design eliminates difficulties encountered with other types and adds no serious new difficulties of its own. Difficulties encountered on this score indicate the futility of complying with certain general principles that may be laid down without giving proper attention to each detail of the new construction. Trouble was encountered in the case of doors fastened with a hook at the top and two fastening screws on the lower part of the door spaced approximately 120 deg. apart. In this particular case the threaded parts that the fastening screws engage are rigidly located and great difficulty is encountered in lining-up the screw holes. This proved to be one of the most unsatisfactory of the new door-fastening mechanisms thus far examined.

We encountered some criticism from head-lamp adjusters in connection with the use of a fiber washer in the connector socket. This fiber washer is used to guide and insulate the socket connector-cable. It swells and sticks, due to dampness, often causing poor contact or no contact with the plug.

Criticism was made of the use of reflector-retaining mechanisms that necessitated distortion of the reflector for installation of the latter. Mechanisms for this purpose should be such that the reflector is held securely and definitely in its proper position without distortion.

Lamp mountings probably came in for more criticism than did any other single detail. In one case the aiming adjustments provided were for rotation in a horizontal plane and in a vertical plane parallel to the car axis, but no provision was made for rotation in the plane perpendicular to the car axis. The elimination of the adjustment in this third plane undoubtedly simplified the aiming of the lamp, but it calls attention to the greater accuracy necessary in locating the beam-modifying device, because, if not accurately located, proper aim of the lamp in this third plane can be obtained only by distorting some part of the lamp or mounting or by relocating the modifying device. A simple method of making this latter correction is not practicable because it is not consistent with the necessary requirement that the beam-modifying device be located definitely.

Attention is called to the necessity for designing the aiming-adjustment parts so that sufficient grip is obtained, when tightened, to prevent accidental changing of the aiming adjustment by pressure that might be exerted by hand. Complication of the aiming adjustment is also to be avoided. The use of the fewest possible number of securing bolts consistent with good design, and the location of the nuts for tightening these bolts above the fender or splash pan is much to be desired.

The strength of lamp mountings calls for the most serious consideration of the automotive engineer. By strength of the lamp mounting I mean not only the lamp-supporting bracket and its attachment to the lamp-shell, but also the parts to which the supporting bracket may be attached. Lamp-supporting brackets usually are attached to the fender-supporting brackets, and weakness of the latter against torsional and bending stresses may render a properly designed lamp-supporting bracket useless. Head-lamps are many times subjected to a force of possibly 75 lb., which acts along a line approximately parallel with the car axis and at a point near the top of the head-lamp. This pressure is exerted by hand while cars are being pushed about in garages and other places, and any part to which or through which this force may be transmitted should be sufficiently strong to withstand it without distortion.

Lamps that, when properly adjusted, are tilted down at an appreciable and unsightly angle have an undesirable psychological effect on the car-owner or operator. Often-times he is inclined to pay too much attention to appearance as compared with results, and sometimes he arrives at certain improper conclusions in regard to results based upon the appearance of the lamp itself. In some cases it was found necessary to tilt the head-lamp so that the front face of the lamp was inclined at an angle of 7 deg. with the vertical when properly adjusted. It will be readily appreciated that such an inclination of the head-lamp may only too easily result in a situation such as that just specified.

Variations in Beam-Depth

The measurement of beam-depth from the head-lamps on five different makes of passenger car is shown in Table 1. Columns 1 and 2 show the results from head-lamps using a striped reflector with plain front-glass. Columns 3 to 10 give the results from head-lamps having paraboloidal reflectors and modifying lenses. The lenses used in the head-lamps from which the data for columns 7 and 8 were obtained, had small beam-deepening prisms on the lower part of the lens, but this prism was covered while the tests were made. All the other lenses had no cross-prisms. All the lenses were of the multi-cylindrical type.

It will be noted that the vertical beam-depth is considerably less in many cases than the approximate equivalent, 31 in. at 25 ft., of the specification, 105 in. at 100 ft., for beam projection from a bare paraboloidal-reflector, proposed by the Subdivision on Head-lamp Construction of the Lighting Division of the Standards Committee. This is due to the fact that the measurements shown in columns 1 to 10 of Table 1 are merely close approximations of apparent beam-depth based upon the observer's judgment and without the use of photometric instruments. Further, these measurements were made in service-stations that could not be darkened completely. Also, by reason of the fact that the spreading of the beam by the modifying lens or reflector reduces the beam intensity, the upper and lower limits of the beam are reduced to an intensity lower than is apparent to the eye of the observer under the stated conditions. In Table 1, column 2, a measurement of 11 in. will be

noted in one case. This measurement probably results from the projection of a horizontal zone of exceptional concentration and high intensity such that the much lower intensities above and below were not apparent to the observer.

The important thing shown by Table 1 is the variation in beam-characteristics. Relative to each other, the figures are fairly accurate; but they should not be taken as absolute determinations of beam-depth, for such measurements can be made accurately only with photometric apparatus. The most common trouble from variations in optical characteristics is indicated by variations in beam-depth. A difference in beam-depth indicates a proportional difference in optical characteristics and generally a vertical displacement of the point of maximum intensity. This usually means that the lamp will give more or less unsatisfactory results in practice.

If the lamp with a vertical beam-depth of 50 in., shown in Table 1, column 8, were mounted 36 in. high on a car and properly focused and aimed, with due allowance for loading with passengers, the center of the main beam, and probably the point of maximum intensity, would strike the road at a point about 25 ft. ahead. This is one of the worst lamps examined, but it shows one of the reasons for the great dissatisfaction with results from the use of improperly constructed head-lamps. The operator of a car so equipped would complain of a lack of sufficient light if the lamps were adjusted to bring the main beam entirely below the level of the lamp centers, and he would criticize strongly the present system of headlighting control. In actual practice it is found that the operator of a car so equipped does not ordinarily have his head-lamps properly aimed, but has them tilted-up so that the zone of maximum intensity will be of some use.

Wide variations in vertical beam-distribution generally result from inaccurate reflectors and improperly located light-sources. Inaccurate construction or assembly causes the latter. In order that a more exact determination of the causes of these variations might be made seven lamps were examined in greater detail and the results are presented in Table 2. In this examination the lenses were removed from the lamps and the reflectors, if not definitely held, were secured in a position corresponding to that in the assembled lamp. These measurements were all taken from lamps with paraboloidal reflectors. Lamps 3*a*, 3*b*, 5*a* and 5*b* show results that are fair to good as compared with results from average reflectors. Lamps 4*a*, 4*b* and 4*c* show results that are very bad and that can be expected to cause complete dissatisfaction in service. Table 2 gives measurements in inches of the diameters of the circles of light on the test-screen at 25 ft. These circles of light were in each case approximately symmetrical about the beam axis, indicating that the filaments were positioned approximately on the reflector axis.

A 4-in. circular blank was cut from a piece of cardboard so that by holding the card with the 4-in. circular hole immediately in front of the reflector or by holding the 4-in. circular-blank in front of the reflector an examination could be made of the beam from the center or from the outer zone of the reflector. Reflectors 3*a*, 3*b*, 4*a*, 4*b*, and 4*c* had an opening of approximately 7 in. Reflectors 5*a* and 5*b* had an opening of approximately 8 in. Column *A* in Table 2 shows the diameter of the beam at 25 ft. when the lamps were focused to bring all the apparent beam within the smallest circle. After this measurement was made, the card with the 4-in. hole was placed immediately in front of the reflector and the beam from the center of the reflector was focused to give

(*Concluded on p. 44*)

TABLE 1—MEASUREMENT OF BEAM-DEPTH IN INCHES ON A SCREEN 25 FT. DISTANT

Right Lamp (1)	Left Lamp (2)	Right Lamp (3)	Left Lamp (4)	Right Lamp (5)	Left Lamp (6)	Right Lamp (7)	Left Lamp (8)	Right Lamp (9)	Left Lamp (10)
21	19	22	19	20	19	26	27	21	18
17	18	23	20	19	20	32	31	17	19
17	19	24	22	18	21	29	32	21	22
17	11	25	21	21	19	31	29	18	23
16	15	19	23	19	18	29	31	26	24
19	18	20	24	23	20	34	29	23	19
21	20	24	23	20	24	28	26	27	18
19	21	20	21	18	22	33	40	23	26
17	17	23	26	19	21	26	50	21	19
16	17	21	24	20	23	33	30	18	22
15	16	22	25	18	20	..	..	18	20
19	17	24	26	20	19	..	..	21	19
18	18	23	22	19	20	..	..	19	27
21	16	28	23	19	22	..	..	24	21
20	18	27	26	24	21	..	..	23	18
17	21	24	27	18	20	..	..	21	27
19	18	23	22	20	19	..	..	19	21
18	20	26	21	27	20	..	..	18	24
16	17	27	22	19	29	..	..	19	21
18	17	27	25	25	19	..	..	21	18
19	16	25	24	22	20	..	..	19	26
15	19	19	22	21	20	..	..	24	26
21	20	26	27	20	19	..	..	19	21
16	18	24	20	19	20	..	..	23	18
..	..	25	24	18	18	..	..	27	24
..	..	..	..	..	..	..	..	22	18

A Diameter of focused beam from whole reflector.

B Diameter of refocused beam through 4-in. hole.

C Diameter of whole beam with *B* focus.

D Diameter of refocused beam through ring outside 4-in. blank.

E Diameter of whole beam with *D* focus.

F Bulb moved from *B* to *D*.

Fundamental Reasons Underlying Modern Safety Coach Design

By F. R. Fageol[1]

Annual Meeting Paper *Illustrated with* Photographs and Drawings

ABSTRACT

THE problem in building the first "safety-coach" was to short-cut evolution—to bridge the gap between what the industry had and what it needed. It is the purpose in this paper to consider the broad fundamentals and underlying principles of the Fageol safety-coach which have formed the basis of subsequent modern motorcoach construction, giving particulars of detailed design only to point out and illustrate the methods of definitely meeting the known needs.

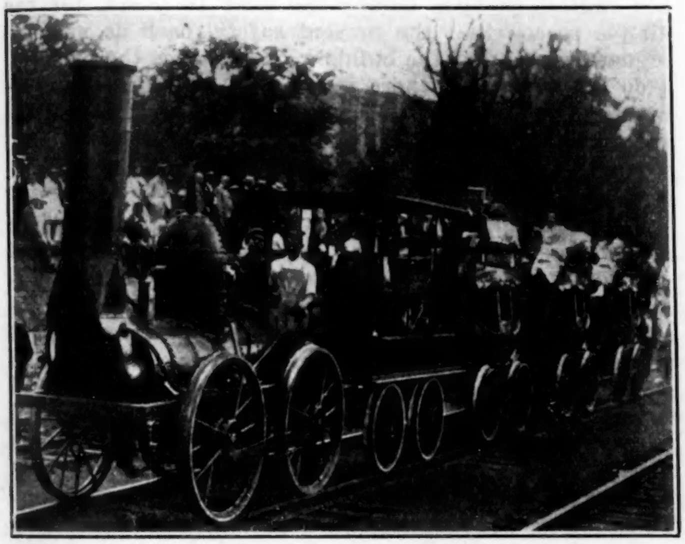


Fig. 1—DeWitt Clinton Locomotive and Coaches
Rolling Stock of the Early Steam Railroads Was Adapted from Horse-Drawn Vehicles of the Day

It was noted that equipment for all types of transportation had undergone a definite evolution, beginning with vehicles designed primarily for some other type of service. The early railroad equipment was adapted from the horse-drawn stagecoach. The first automobiles were literally "horseless carriages." The first motor-stages were adapted from the touring car or the truck. Either of the latter was good for the purpose it was designed to fulfill—both had great shortcomings in public motor passenger-service.

Taking as a guide the experience of the railroads as sellers of commercial transportation, it was found that the first requisite for the ultimate motorcoach was ability to serve best and attract patronage. The yardstick by which the equipment would succeed or fail would be its ability to sell rides, and the requirements for this passenger popularity were safety, comfort, convenience features, and dependability, coupled with operating economy. The passenger automobile has fixed not only the riding habits of the public but the rate of acceleration and speed up-hill or on the level. Any vehicle that does not closely approximate these conditions must ultimately fail in the transportation field and become a menace to traffic.

Since all the available commercial engines were designed for either low-speed trucking or relatively light-weight passenger-car service, it became necessary to design a new engine that contained the characteristics of enormous torque at low speeds and power enough for 45 to 50-m.p.h. service, with practically no vibration at any speed. The design of this engine was intrusted to E. J. Hall.

For the chassis of the coach it was necessary to reduce the floor height, lower the center of gravity and spread the wheels apart so that it would not only be actually but obviously safe. Bodies for city and interurban service were designed with a view to comfort and convenience and were constructed to take-up torsion due to uneven road surfaces without damage to the body.

Many refinements have been made during the last 4 years, but the main fundamentals of construction, developed through investigation before starting to build, have not been deviated from, and the early conclusions of the designers seem to be confirmed by the

Fig. 2—First Automobile Built by Fageol Bros. in 1899
This Was Practically a Hand-Made Vehicle and Was Built in Their Father's Barn in Iowa. It Shows Clearly the Typical "Horseless Carriage" Influence of the Pioneer Automobile Period

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almost unanimous adoption of the main features of design as the standards of the industry.

THE message that I would like to convey to the engineering fraternity is that the greatest problem involved in motorcoach design is selling rides. The questions really are: "What does the riding public want?" and "What will best suit the public requirements and convenience?" A motorcoach may be mechanically excellent, but if it does not tend to sell rides it is really a failure. When the Fageol Motors Co. decided to enter the motorcoach field a little more than 6 years ago, we started out fresh with the firm desire to build vehicles that would be serviceable, comfortable, economical, and strong.

Buses of that day were improvised largely by the operators themselves from motor vehicles that had started life either as passenger cars or as motor trucks. For the most part they were unduly heavy and under-powered for their carrying capacity, were greatly lacking in riding-comfort and appeared to be anything but safe. There was no standardization in the industry. For example, an operator might have in his fleet not only several makes of engine and parts, but several models of the same make. These were joined into a semblance of a motorcoach by hand-tooled parts made in small quantities and many varieties. Construction was governed largely by rule of thumb, and the savings effected by standardized construction were impossible.

With these points in view, we sent members of our organization all over the Country to study existing motorcoach operating-requirements and conditions. They received their information first-hand, not only from people who operated but also from those who rode in the vehicles. They returned with a long list of needs and data. These were reflected and met as nearly as possible in the design of our product. We have since kept the results of this primary survey of the field foremost in our minds.

The Evolution of Transportation Equipment

During this early period we investigated thoroughly the history and evolution of the steam locomotive, which derived its initial design from the animal-drawn vehicle. The early railroad-coaches were really the old horse-drawn stage-coaches with flanged wheels adapted to them, as shown in Fig. 1.

We considered each step in the evolution and development of the locomotive down to the present time and tried to satisfy ourselves as to why the changes had been made and why the modern locomotive has distinctive, sturdy, safe, business-like proportions and why our modern railroad-coaches have taken on their present design. All this was analyzed from the human or passenger viewpoint.

It is always an inspiration to me to study the early designs of steam-railroad equipment exhibited on the balcony of the Grand Central Terminal, New York City, because there I see the first stage in the development of rail equipment in its change from adapted wagons to the specialized transportation equipment that we see today. Through the exhibit comes understanding of the slow and steady development through a century from the vehicle that was known to the vehicle that was needed.

We next took up the early automobile, as illustrated in Fig. 2, and found that it was really a horse-drawn vehicle with the shafts and horse omitted and an engine substituted therefor but in many instances still carrying the whip-socket. You are all familiar with what happened to this vehicle during the last 15 years, but I doubt whether most of you have seriously analyzed why it happened. The reason for the evolution of both the locomotive and the automobile can be seen in the fact that the vehicles now come nearer to suiting the public's needs. The problems involved and the proper answering of them explain all evolution and improvement of design.

Next we came to the motorcoach. We found that all builders were following the natural trend, beginning by using an automobile or a motor-truck chassis of that day, neither one of which was ever designed or intended for this class of work. Our organization, with a keen appreciation of the great advantages of the modern design of locomotive over the original, and of the modern design of automobile over the original, simply tried to analyze the problem involved in motorcoach design and to look ahead to the design that would finally be created by evolution. We tried to create that design and "short-cut" 10 to 15 years by building a motorcoach that would answer the problem. The first Fageol safety-coach, called the Silver Fox, gave the answer to our version of the problem. The old Silver Fox was introduced on Feb. 6, 1922.

We do not believe that modern motorcoach design will see radical changes during the next 10 years, for the simple reason that the present safety-coach as now designed by many of the builders really solves the problem. I do not mean that there is not vast room for improvements in many details. I mean that the fundamental design will see very little change.

The Modern Motorcoach

The high-lights of our analysis which led to this design are substantially as follows: The motorcoach had created a new class of service, with requirements that were different from those of any service theretofore known in the automobile industry. The yearly motorcoach mileage is much higher than anything previously contemplated in motor-vehicle design. Therefore engines, chassis and bodies that had been designed for ordinary commercial purposes, wherein 15,000 to 20,000 miles per year was rarely exceeded, could hardly be expected to answer this new call with requirements up to 100,000 miles per year. This was particularly true of engines, because really up to that time practically no fundamental changes had been made during the previous 10 years, notwithstanding the fact that the industry had developed several excellent engines that were well suited to the purposes for which they had been designed primarily.

Ways and means had to be found to keep the motorcoach on the road more days per year. This required not only sturdier construction of all parts subject to wear or breakage, but also a design that would more readily enable the operator to keep his coach continuously in service and also shorten the time required for its maintenance or repair.

Any business that depends on the public for its revenue can reach its highest development only by carrying an attitude of "the public be served" through every phase of its activity. Equipment had to be designed that would not only attract a greater number of passengers on account of its unmistakable safety and suitability for the purpose but also render more dependable service at lower expense. Axles, transmissions, drive-shafts, brakes, tires, body, finish, upholstery and ventilation, in fact, the entire mechanism, had to be brought up to the standard required by 100,000-miles-per-year service, day in and day out, consistently and continuously on the job, if we were to bridge successfully the gap between what the industry had and what it needed.

The passenger automobile has established not only the

riding habits of the public but also the rate of acceleration and speed up-hill or on the level, and any passenger-carrying vehicle that does not closely approximate these conditions must ultimately fail in the transportation field and become a menace to traffic. Compare in your mind's eye what we found in our early investigation with the motorcoach of today, with its sleek, well-groomed body, its attractive appearance, its comfortable interior with deep soft seats that invite patronage, the deep purr of its high-powered engine that quietly and swiftly carries the vehicle along the ribbons of highway—all this in a few short years. On the whole, the evolution of the

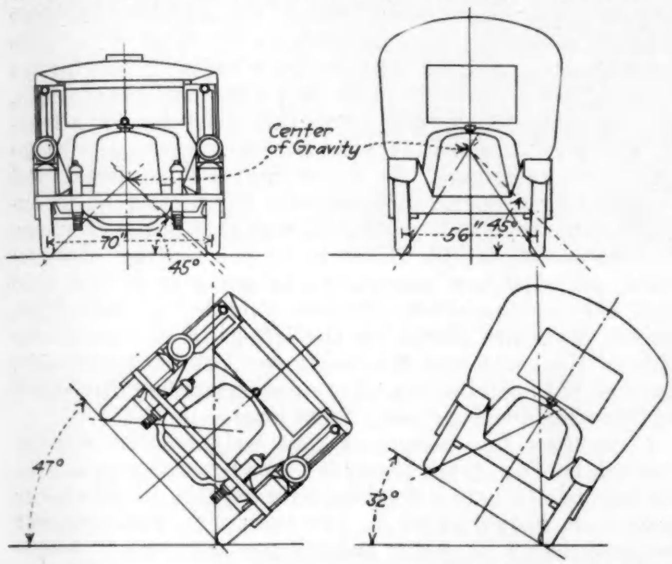

FIG. 3—EFFECT OF LOW CENTER OF GRAVITY AS A SAFETY FACTOR
The Fageol Safety-Coach Can Be Tipped to an Angle of 47 Deg. Before It Will Turn Over, Whereas the Safety Angle of a High Center-of-Gravity Coach Having Standard 56-In. Tread Is Only 32 Deg.

motorcoach has been phenomenal in its rapid rise to heights of efficiency and beauty. The ugly duckling of motorbusdom has grown to be worthy of the industry.

When we started, the only experience we could take as a guide was that of the few operators then in the business, whose operations in mileage were, judged by present-day standards, very limited. Our first conception of the fundamentals of motorcoach design must have been correct, for, today, with Fageol safety-coaches being operated 70,000,000 miles annually, we see no reason to change the main features of design. In fact, the influence of this design on the industry has been so profound that the operator cannot now go far wrong in buying equipment from any of the leading companies that are really specializing in modern motorcoach construction. We are glad that this is so, because any condition that tends to strengthen or make the industry on which we depend for our livelihood more secure can only broaden the field for all of us and create better conditions surrounding our business.

CENTER OF GRAVITY LOWERED

The first requisite was to bring the whole vehicle closer to the ground to get rid of the top-heavy appearance and to eliminate the side-sway that was one of the main factors in the public's lack of confidence in the motorcoach of that day. To accomplish this, it was necessary to design a totally new chassis from the ground up. To lower the center of gravity, the wheels were spread farther apart than had previously been the practice, and a special drop-frame, with goose-necks over the front axles and kick-ups over the rear axles, was constructed. Using

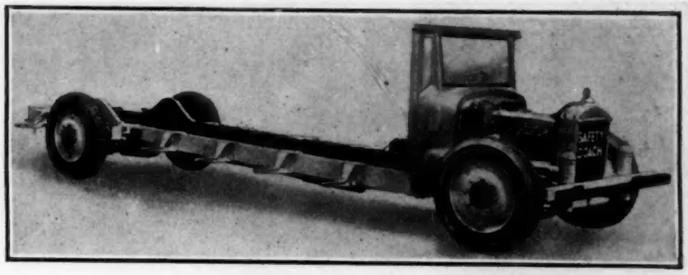

FIG. 4—CHASSIS OF THE FAGEOL SAFETY-COACH
The Front and Rear Frame-Arches Make It Possible To Build the Coach with Low Frame, Low Floor and Low Center of Gravity. The Frame Is Somewhat Flexible

axles 14 in. wider than the standard vehicle-tread, we spread the frame-rails as far apart as was practical to allow clearance for steering and brake-drums, and placed the springs as far apart as was practicable, to eliminate side-sway. This type of construction, together with certain other structural features, enables us to get a floor-height of only 24 in., at the same time retaining the numerous advantages of easy riding and low tire-expense afforded by the 36-in. tire.

In this way the center of gravity was lowered until our intercity model could be tilted to an angle of 47 deg., as is brought out in Fig. 3, before passing the ultimate point of stability, where the perpendicular through the center of gravity passed outside the extreme support afforded by the tire. The design was laid out so that the wheels were relatively near the corners of the load, which not only afforded stability but also, in combination with the low center-of-gravity, offered a means of eliminating much of the strain imposed on tires when rounding corners and served to increase the life of tires materially.

On the basis that either the road had to be flattened out and all unevenness taken from it, or the frame made to adjust itself in some measure to the irregularity of the road-bed, we chose the latter as the lesser of two evils. Aided by the flexibility of the springs, the frame is partially able to adapt itself to the road irregularities. This has assisted in securing easy riding. The frame cross-members are of channel construction, heavily gus-

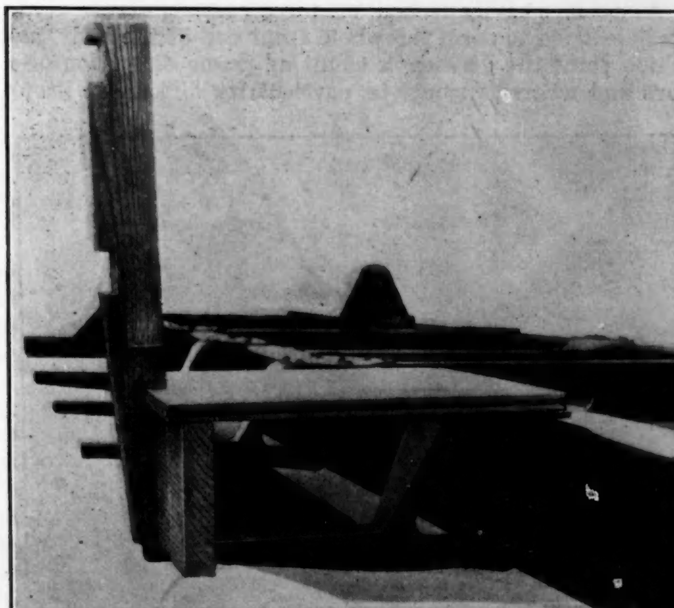

FIG. 5—DETAIL OF BODY FRAMING
The Body Is Supported on Cast-Steel Brackets, Which Permit a Low Floor-Level. The Method of Framing and Flooring Strengthens the Body against Longitudinal and Lateral Torsion

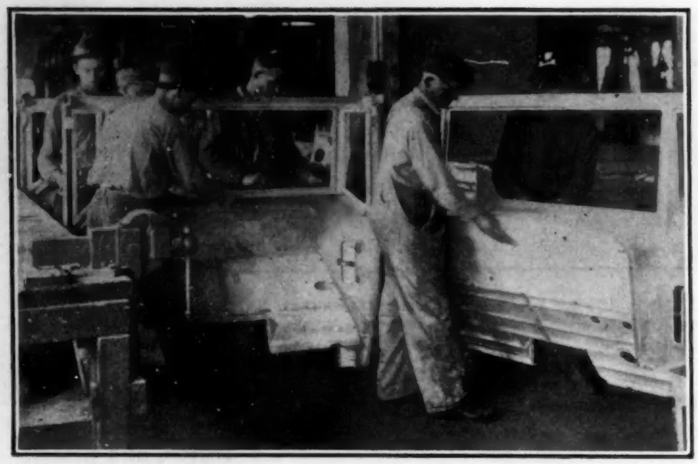

FIG. 6—ONE-PIECE CAST-ALUMINUM FRONT END
Cowl, Windshield Frame and Dash Are Formed in a Single Rigid Piece That Avoids Looseness and Rattling

seted, and designed so that the frame-rails may twist slightly out of parallel as required. (See Fig. 4.)

Since the frame design is not absolutely rigid, it is necessary to build the body to conform to the movement of the frame. The body is therefore semi-flexible in the same direction as the frame. To prevent longitudinal motion and still retain the ability to resist lateral strain, we use a $2\frac{1}{2}$ x 6-in. main bottom-sill set on edge, this sill being rabbeted $\frac{1}{4}$ in. where the upright post is fitted in. This joint is then glued and each upright held solidly to the sill by two carriage bolts. This amply takes care of the longitudinal strains, and the lateral strains are taken care of by bolting the side-sills through the cast-steel body-support brackets and rigidly screwing the floor to the tops of the sills to form a cross-brace. The main cross-sills of the floor, which are about $1\frac{1}{2}$ in thick and placed flat, are then bolted through the gusset plates of the frame, so as to make a rigid box-like construction, which absolutely prevents side-sway. The floor itself is $\frac{3}{4}$ in. thick and very light in weight. (See Fig. 5.) In this manner, a body has been constructed that does not depend upon the bracing of the seats for support.

A special heavily ribbed one-piece cast-aluminum cowl was designed to form the whole front end of the body, at which point the greatest amount of frame distortion occurs and where it would be particularly difficult to keep a fabricated cowl from loosening and rattling. This also makes practicable the use of readily removable aluminum toe-boards, mounted on permanent ledges. The aluminum cowl also gives a graceful and finished contour to the body and facilitates the design of appealing body lines, as is shown in Fig. 6.

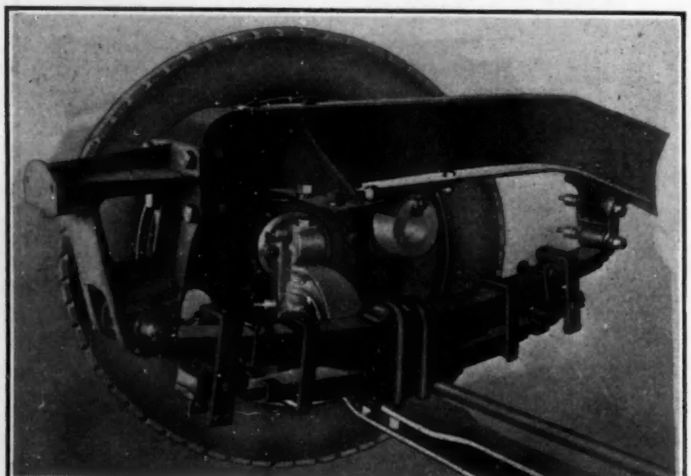

FIG. 7—FRONT-AXLE, SPRING AND WHEEL ASSEMBLY
The Two-Stage Spring Construction, with Rubber-Block Cushions at the Ends of the Helper-Spring, Cushions the Variable Load and Has a Snubbing Action

BODY HEIGHT AND WIDTH

There has been more or less discussion as to the proper width and height of body. The problems involved really answer this discussion, because, if four people are to be seated abreast, with aisle space, we must allow two 34-in. inside-measurement seats, which are about 36-in. wide overall, plus the minimum of from 12 to 14 in. of aisle room, plus the thickness of the body walls. These figures give a total of from 90 to 92 in. for the minimum width. It is not practicable to go below this minimum for a four-seat center-aisle motorcoach, nor is it necessary to go above the maximum. In a few States it is illegal, and under certain operating-conditions impracticable, to operate vehicles of this width. Where this is the case, one has no choice except to cut down the seating arrangement, allowing two passengers on one side of the aisle and one on the other. Where this is necessary, the double seats are placed on the left-hand or road-crown side of the coach and the single seats on the right side, so that the distribution of weight minimizes the effect of throwing the floor away from level.

Experience has taught us that body heights may be limited to two types—the full head-room, pay-as-you-enter type for urban or short-haul service, in which the head-room should never be less than 6 ft. and need not be more than 6. ft. 6 in.; and the semi head-room vehicle for interurban or long-haul service, in which 5 ft. 6 in. represents the maximum requirement. There are many operators who argue in favor of the full head-room motorcoach for even the longer interurban runs, and, since the low floor-level makes it practicable to design an attractive-looking vehicle with full head-room, it really matters little which type is used for interurban work.

The baggage problem, which is a most serious one, is better solved by using the semi head-room vehicle, which more readily permits of putting baggage on the roof, and, notwithstanding that carrying baggage on the roof has all the appearance and all the inconveniences of a makeshift or emergency arrangement, nevertheless no one has been able to offer a more satisfactory answer to the problem. Incidentally, the baggage-carrying problem is becoming more serious every day, and it is entirely possible that, if the motorcoach is to become a general transportation medium on runs of up to 100 or 150 miles or more, it may eventually be found necessary to operate separate vehicles for transporting the baggage and general express between terminals. This is a problem that only a careful study of future developments will answer satisfactorily.

Very little has been done toward the improvement of springs or riding-quality of springs during the last 15 years. The motorcoach presents one of the most difficult spring problems in the automotive industry, because of the great variations in both load-factors and speeds. The ideal solution of these problems is a spring, the effect of which can be varied to suit the changing load and road conditions. To adopt a spring that is absolutely ideal in this regard is, we believe, impracticable under the present understanding of spring construction, but as a step in this direction we have been able to achieve satisfactory results by the use of what we term a two-stage or variable-load spring. This is really a further development

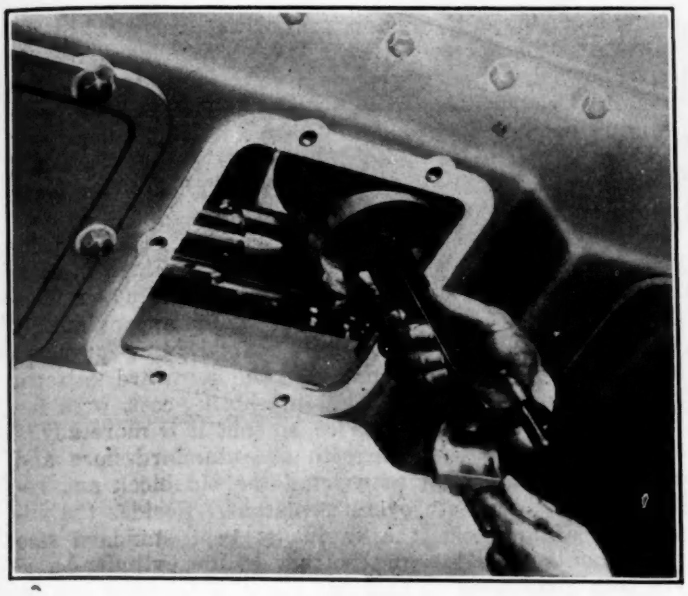

Fig. 8—Hand-Holes in Base of Crankcase
The Pistons Can Be Removed through the Hand-Holes without Removing the Lower Half of the Crankcase

and improvement of the old Hoover helper-spring that has been in use to some extent for the last 12 or 15 years.

We have departed from the Hoover idea in that we make our lower or helper set of springs practically the same length as the main spring and have worked on the theory of making the helper-spring pick-up the load from its tip contact instead of from the center point, because of the well-understood fact that the flexibility of the spring increases in a sort of geometrical ratio toward the tip but has relatively little action near the center. To put the load on the tip of the helper-spring and to overcome the noise of intermittent contact between the tips of the helper and main springs, rubber blocks are mounted on top of the helper-spring ends. This construction also permits the use of the helper-spring as a snubber for the main spring by connecting the two with a steel loop, as shown in Fig. 7. This snubber action is really as essential as the flexibility of the entire spring-unit, as a spring flexible enough to give easy riding under light-load conditions also has a tendency to throw.

The full-floating, underslung, worm-type of axle has been found very satisfactory under all operating conditions. By providing a high factor of safety in all parts, axles of this type require under ordinary operating conditions only lubrication and occasional adjustment of bearings, unless they are damaged by totally unforeseen causes.

It has been the experience of both the European and the American builders that the worm-drive axle retains practically the same degree of efficiency throughout its entire life, whereas other forms of drive, depending on spur gears, undergo a constantly increasing loss of efficiency. Results with the underslung worm have been particularly gratifying, showing very little wear after from 200,000 to 300,000 miles of service. We have found that the full-floating type has several important advantages over the semi-floating. It makes operation safer because, in case of an axle-shaft failure, the wheel does not come off and drop the load. The vehicle can also be readily towed in, or a new drive-shaft installed on the road with very little delay. We further find it more practicable to make a grease-tight packing-joint at the inside bearing of the hub to prevent leakage of lubricant.

To meet the requirements for a really satisfactory motorcoach engine, it was necessary to design the entire unit completely. The requirements to be met for such an engine were economy of operation, economy of replacement of parts, long life, ease of servicing, interchangeability of unit assemblies, high torque at low speeds, rapid acceleration, and freedom from vibration and noise.

Economy of Operation

Good average economy is more to be desired than extreme economy of one kind at the expense of economies of other kinds. As an example, I call attention to the fact that extreme economy in lubricating oil may result in a very high maintenance and service cost, whereas an average oil consumption would result in low maintenance-cost and long life of the engine. In the engine used in the Fageol safety-coach, an excellent balance has been obtained between various kinds of economy. The fuel consumption per brake-horsepower-hour, as well as per ton-mile or passenger-mile, is below the average, and yet is not reduced to the point where overheating causes high maintenance-costs. The oil consumption is very satisfactory, being in the neighborhood of 1 qt. per 150 miles.

Maintenance costs on the engine are very low, due largely to the fact that it has been designed of such materials that very little service is required. The design is also such that servicing the engine in the chassis can be done easily and in a very short time. As an example, with one complete head-assembly, an entire fleet of motorcoaches can be serviced as to valve-grinding, each head-change occupying about 45 min. The pistons and connecting-rods can be withdrawn from the engine by removing the lower crankcase hand-hole plates and without disturbing any other parts. The main bearings and connecting-rod bearings can also be inspected through these same hand-holes which are shown in Fig. 8. Pistons and connecting-rods are so accurately balanced as to weight that no difficulty is experienced in changing one rod and piston of a set without changing the others.

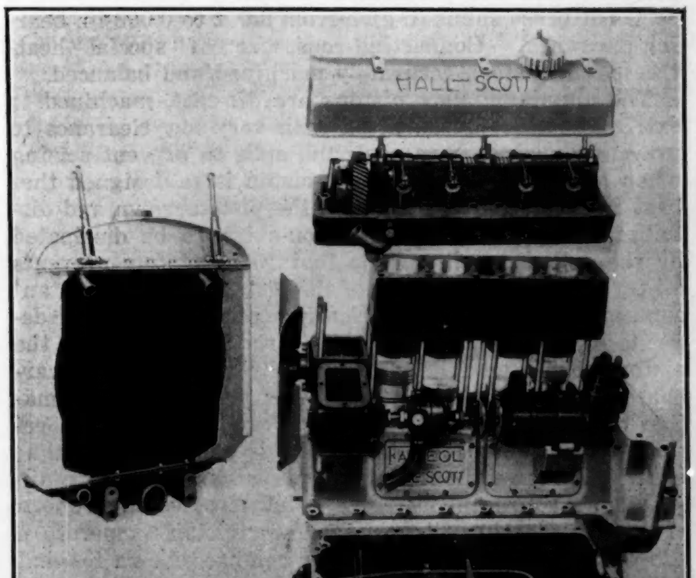

Fig. 9—Fageol-Hall-Scott Engine
This Is Built of Separate Interchangeable Unit-Assemblies To Facilitate Service-Work and Save Time when Making Replacements

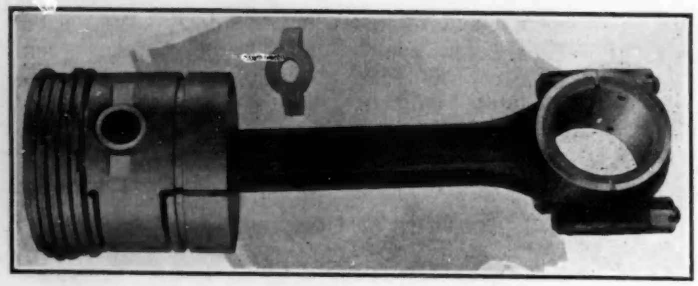

FIG. 10—PISTON ASSEMBLY, SHOWING WRIST-PIN RETAINER

REPLACEMENT OF PARTS

The engine is designed so that it is made up of major assemblies, which are strictly interchangeable, for ease and economical replacement of wearing parts. Later developments or improvements may be readily incorporated in older models. Subassemblies are interchangeable. The engine, which is illustrated in Fig. 9, should, theoretically, never wear-out if properly lubricated and maintained.

The crankshaft is forged from a special alloy-steel that is very hard and tough, and is accurately machined and ground and lapped to a very fine finish on all wearing surfaces. We can cite many cases of crankshafts running 100,000 miles and showing only 0.001 or 0.002-in. wear on the journals. The rigidity of the crankshaft and the large diameter of the bearings give extremely long bearing-life. Adjustment of the bearings is rarely necessary under 50,000 miles. Bearing shells are of bronze-backed babbitt, accurately machined for interchangeability in the crankcase, and are secured in place by rivets. In building the engine, bearings are burnished, making practically 100-per cent bearing surface, providing maximum bearing-life. The bearings are burnished-in one at a time, until each bearing offers a certain amount of resistance to the torque of the motor that rotates the crankshaft. The bearings are assembled for burnishing with hardened and ground steel-shims, which are then removed and the permanent assembly remade with a series of brass shims to give from 0.002 to 0.003-in. bearing-clearance. Connecting-rods are of special heat-treated alloy-steel, accurately machined and balanced.

The aluminum-alloy pistons are die-cast, machined to extremely close limits, fitted with very low clearance to prevent slapping when cool, and split to prevent seizing when hot. The section of the piston is so designed that heat is conducted rapidly from the piston-crown and distributed uniformly to the piston-skirt, to be dissipated by the cylinder-walls. This feature absolutely prevents oil-frying on the underside of the piston and the resultant contamination of the lubricating oil with carbon deposits; prevents objectionable carbon deposits on the piston-crown and resultant preignition from either carbon or an overheated piston-crown; prevents the formation of carbon in the piston-ring grooves, with the resultant ring-binding and scoring of cylinder-walls; greatly increases the life of the piston-pin and piston-pin bushings by preventing these points from being robbed of their lubricating oil; and the lower piston temperature allows the employment of higher compression-ratios and the resultant fuel-economy.

The piston is fitted with six rings that have been designed to provide uniform ring-tension throughout the life of the ring, maximum cylinder-wall lubrication without passage of oil to the combustion-chamber, maximum ring-life, and uniform wear on the cylinder-wall. The piston-pin is free in both the piston and connecting-rod ends and is held central by piston-pin retainers of the same material as the piston, pressed in place slightly below the piston surface. (See Fig. 10.) We have never, to our knowledge, had to replace a piston-pin or piston-pin bushing, in normal service, inside of the regular overhauling period at 100,000 miles. We have developed our pistons and cylinder-blocks to a point where piston and cylinder-block wear is uniform. They rarely ever wear out-of-round or taper.

The cylinder-block is a separate casting, simple in design and inexpensive. Cylinder bores are chilled in casting and are accurately bored and ground, and when properly lubricated have a normal life of approximately 100,000 miles. The simplicity of the casting prevents warping and uneven expansion; it tends toward uniform wear and makes possible a low machining-cost, with the resultant low-replacement price, so that it is more advisable to buy a new block with the standard bore and standard pistons than to regrind the old block and replace the pistons with oversize pistons. Besides the advantage of low cost, the engine is kept standard size throughout. The top and bottom of the cylinder-bores are both chamfered so that the piston assemblies can be inserted from either the top or the bottom as is more convenient.

THE FRONT-END DRIVE

The sprocket-housing assembly has been carefully worked out. The chain is of such width and capacity that its normal life should never be less than 100,000 miles. We have seen several that were still in service at 300,000 miles. The sprockets on which the chain runs are of heat-treated alloy-steel, very tough and hard, of large diameter and all of exactly the same size. The large diameter minimizes the wear on the chain joints and adds to the number of teeth carrying the load. The sprockets themselves revolve about shafts that are supported at both ends so that the sprockets never wabble and throw excessive load on one side or the other of the chain. Proper adjustment gives maximum chain-life. With this in view, an accessible eccentric chain-adjustment has been provided in the sprocket housing by means of which the chain tension may be corrected in 5 to 10 min. (See Fig. 11.)

The fan is positively driven from the fanshaft in the upper part of the sprocket housing. The fan drive-shaft and bearings are sealed against dirt by a grist-mill seal and felt washers.

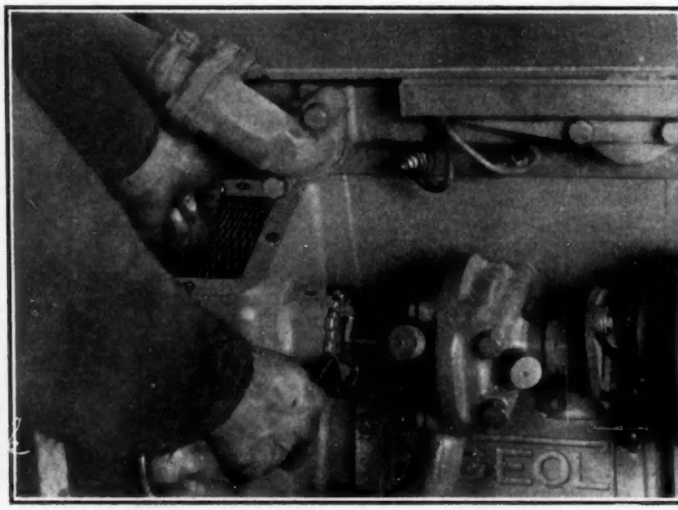

FIG. 11—ADJUSTING FRONT-END CHAIN-DRIVE
The Silent Chain Runs over Three Large Heat-Treated Alloy-Steel Sprockets, One of Which Is Encased in the Housing Shown and Is Easily Adjusted

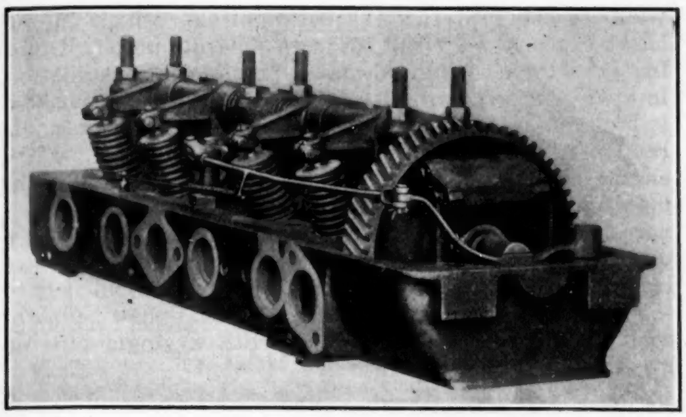

Fig. 12—Interchangeable Cylinder-Head Assembly
This Is Complete with Valves and Valve-Operating Mechanism and Can Be Removed and Replaced in 45 Min. It Is Interchangeable with All Others of the Same Model

The cylinder-head design is unique. The valves, camshaft and valve-operating mechanism are all mounted on the head, which is easily removed for service purposes. This is of particular value in fleet operation. One spare head makes possible the servicing of an entire fleet. It is only necessary to remove one head-assembly and drop the other in place. Valves may be ground and tappet clearance adjusted, ready for operation, with the head on the bench. The camshaft, being mounted on the cylinder-head, can be removed easily if necessary, without disturbing any other major assembly. The camshaft is positively driven by a large helical-gear at the forward end, which meshes with a gear on the fan drive-shaft in the upper part of the sprocket housing. The design of the valve-operating mechanism is unusual in that both valves are operated by one cam, the camshaft having but one cam for each cylinder. (See Fig. 12.)

The rocker-arms are of bell-crank type, transmitting the motion directly from the cam to the valve, which makes possible maintaining the tappet adjustment throughout the range of operating temperatures and provides an absolutely quiet valve-action. The exhaust and intake rocker-arms are identical and have a wide-face shoe, which provides a large wearing-surface on the cam, with resultant long life.

The valves are of large diameter, the exhaust-valve being of a special material capable of withstanding extremely high temperatures. The portion of the valve-stem where the tappet screw bears is hardened to make possible the maintenance of valve tappet-clearance over long periods. The average valve-grinding period is 25,000 miles.

The water-pump is mounted on the cylinder-block and driven from the sprocket housing at engine-speed. The pump-shaft is of special stainless-steel, hardened and ground to close tolerances, the pump-runner and all couplings being attached by splines. The material used, coupled with the close tolerances, assures extremely long life of packing, and prevents scoring. The water-pump body is made of gray cast-iron to eliminate chemical action due to alkaline water; the impeller is of cast bronze. The pump-shaft forms the accessory drive-shaft.

The electric generator is mounted on a special bracket on the middle upper-crankcase hand-hole plate and is driven by the accessory shaft at engine-speed, which results in extremely long life of the commutator and brushes. The generator is of 400-watt capacity, especially developed for motorcoach service, and in addition to taking care of the regular battery-charging and ignition will provide ample current to supply 12 to 16 lamps of 21 cp., depending on the nature of the service. Provision is made to mount a 3-cu. ft. Westinghouse air-compressor on the rear upper-crankcase hand-hold plate. The generator armature-shaft, of heat-treated alloy-steel, is of sufficient size to provide for driving the directly connected air-compressor. (See Fig. 13.)

Lubrication

Oil is distributed from the oil-sump to all parts of the engine under pressure. The oil is pumped from the sump through a screen and forced through a main oil-line in the crankcase to all main and connecting-rod bearings. In passing from the oil-pump to the main bearings, all of the oil is forced through a special filter of Hall-Scott design, which removes the impurities. The oil-pump is located at the forward end of the engine and is fitted with an oil-pressure relief-valve that maintains a nearly constant pressure in the oil-lines. The oil-filter is located at the forward end of the upper crankcase on the manifold side. It consists essentially of a casing, a series of compressed-felt washers and a bypass-valve.

Oil is delivered from the oil-pump directly to the outer casing of the oil-filter. It is forced through the edge grain of the compressed felts, into the hollow stud in the center. This hollow stud delivers oil directly to the oil-lines in the engine, all of the oil used going through the filtering process. The oil-filter is fitted with a bypass-valve of such a design that, should the felts become clogged, due to neglect, or the filter for any reason cease to function, the valve will open and allow the oil to bypass into the oil-lines without going through the felts. (See Fig. 14.)

An auxiliary oil-line carries oil from the main oil-line across the upper case and up through the sprocket housing, to supply the bearings of the accessory shaft and adjusting sprocket. At the flywheel end of the engine is a hollow hold-down stud that carries oil from the main crankcase oil-lead to the hollow rocker-arm shaft, from which it is metered under pressure to both the camshaft and the rocker-arm bearings. The excess oil flows over the cylinder-head and into the camshaft trough, so the cams are constantly half-immersed in oil. This process ensures ample lubrication for valve-stems, rocker-arm contacts, governor, and all its operating mechanism, including the governor-throttle valve-stem.

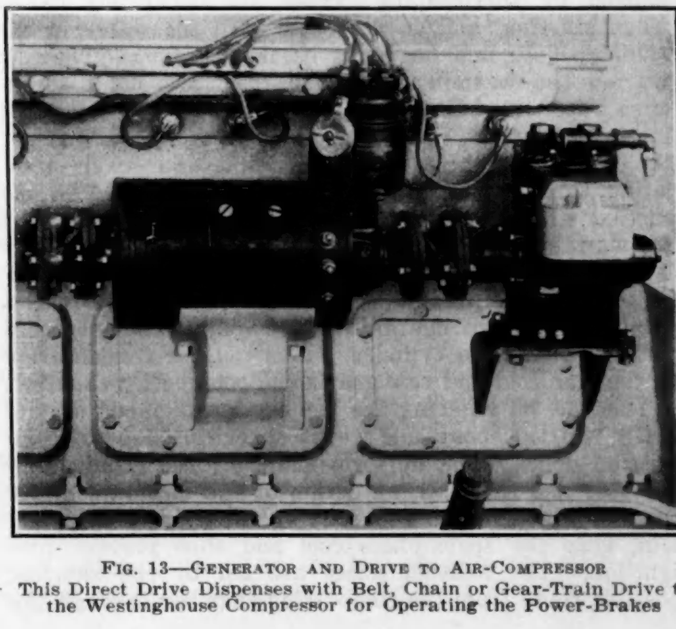

Fig. 13—Generator and Drive to Air-Compressor
This Direct Drive Dispenses with Belt, Chain or Gear-Train Drive to the Westinghouse Compressor for Operating the Power-Brakes

The oil flows from the rear end of the cylinder-head to the front end of the engine, down over the camshaft gears and chains. In the return of the oil from the cylinder-head to the crankcase, the oil is aerated; this, aided by the heating of the oil as it flows over the cylinder-head, causes most of the fuel diluent and condensate to be driven off as vapor. The escape of these vapors from the engine through the large breather in the top of the valve-cover, is facilitated by the fact that an auxiliary breather located in the rear of the crankcase allows the entrance of fresh air at that point.

Our oil-filter is deserving of special mention. A differential in pressure of from 5 to 7 lb. is caused by the filter, that is, the pressure at the pump is from 5 to 7 lb. higher than that in the oil-lines. The oil, in going through the felts, is forced through the carbon, tar, sludge, and the like, already formed on the felts, thus filtering the oil through its own impurities. Excess sludge forming on the felts runs down and is retained in a drainable sump at the bottom of the filter.

If moisture, carbon or other binders can be kept out of the lubricating oil, diluents will not be readily absorbed and will be driven-off through the breathers. Moisture, soluble asphalt, carbon particles, road dust, metal particles, and other impurities are effectively removed by our filtering process, and dilution is reduced to the minimum. It is not necessary to change lubricating oil oftener than once every 2 or 3 weeks, or from 3000 to 5000 miles in urban service where many stops and starts are made, small mileages are covered and low temperatures are encountered; 7500 to 10,000 miles may be covered in jobs in fast intercity service, or where long mileages are run with few stops and higher temperatures are maintained. This filter does actually remove moisture, as moisture cannot pass through the carbonaceous sludge-formation collected on the felts.

The oil-pressure relief-valve is adjusted at the factory to maintain an oil pressure of from 15 or 16 lb. at 600 r.p.m. to 28 or 30 lb. at the bearings at the governed speed of 1700 r.p.m.

Cooling

The engine cooling-system is built into the powerplant. The radiator is mounted on the engine, which facilitates complete running-in of an engine, even though it be not mounted in a chassis. The temperature control is accomplished by thermostats. These are completely closed when starting, and do not open until the water in the cylinder-block and head has become thoroughly heated During the warming-up period the water-pump circulates water through the cylinder-block, cylinder-head and intake-manifold. This water is taken from that part of the head where heat is first available and, after circulating through the intake-manifold, is returned to the suction side of the water-pump. In this way the time for warming-up is greatly reduced. Additional efficiency is obtained by the manifolding within the cylinder-head. The intake manifolding is arranged so that the incoming gas-mixture is maintained at a constant temperature until it enters the cylinder. This reduces condensation in the manifold and raw gas in the combustion-chamber.

The gas, on entering the combustion-chamber, is violently whirled about, due to the spherical shape of combustion dome. The uniform shape of the combustion-chamber and the whirling action of the incoming gases, some of which impinge directly on the spark-plug porcelain, keep the spark-plugs cool and thus prevent preignition. The exhaust gases are led by the shortest possible route from the combustion-chamber through the water-jacket into the exhaust-manifold, which in our latest engines is divided into two separate pieces. Dividing the exhaust-manifold makes possible the installation, in a wide-tread coach, of a forward manifold-section that is brought in close to the engine to clear the hood, and a rear manifold-section that, while not so close to the engine, still clears the hood sufficiently. Dividing the manifold into two parts reduces the weight and eliminates all trouble from expansion that would occur if both parts were made in one casting. The exhaust-pipes are led parallel to each other from the exhaust-manifolds to the muffler. It is possible with this dual exhaust-pipe to cool the gases much more than with a single pipe of greater size.

Gassing

In many localities gassing is proving to be a rather serious menace, and we have carried on many interesting experiments to isolate the causes and eliminate them. The baffling part about gassing is that it is not consistent; that is, a certain vehicle on one day will apparently not gas at all, whereas perhaps on the next day the exhaust-gas odors will be most objectionable. All of this happens without making changes of adjustment of any kind. It being obviously advantageous to mix these gases with the greatest possible volume of air at the earliest possible moment, we terminate the exhaust-pipes on the left side of the coach just ahead of the rear wheel, so as to take advantage of the somewhat compressed air-condition along the side of the motorcoach. The rotation of the wheel also tends to act as a mixer.

Additional good results have been obtained by making something like an ejector over the end of the tail-pipe, the ejector tending to dilute the gases immediately after they leave the motorcoach. We consider the rear end the worst possible place to terminate the exhaust-pipe, on account of the partial vacuum created by the moving vehicle, which causes the exhaust gases to cling to the rear of and find their way into the motorcoach when it stops.

One of the unique service features of this engine is the valve-timing. The flywheel housing is provided with a plunger that can be dropped into contact with the outer surface of the flywheel. The crankshaft is then rotated slowly by hand until the plunger snaps into a hole in the flywheel. With the valve-cover removed, the mechanic has only to see that the forward cam stands absolutely vertical between the two rocker-arm shoes, and the engine is timed. In changing heads, it is the work of but a moment to set the cams in the proper position and, with the crankshaft in the proper position as determined by the timing-index, the head is simply lowered over the studs and tightened down.

A large pipe-plug is provided in the bottom of the flywheel housing. The crankshaft is then rotated until a smaller pipe-plug in the flywheel comes into view. This is then removed, a grease-gun connection screwed in and lubricant forced to the pilot-bearing through a channel drilled through the flywheel.

Having obtained an engine that incorporates all the essential features conducive to long life, we decided that some assurance must be found to prevent abuse by the operator. This has been obtained by incorporating in the engine itself a governing system that can be adjusted and sealed so that the engine cannot be run at a greater speed than desired by the owner. The governor-actuating mechanism is built into the camshaft gear and operates butterfly valves located in the intake-manifolds. The complete governing-mechanism is

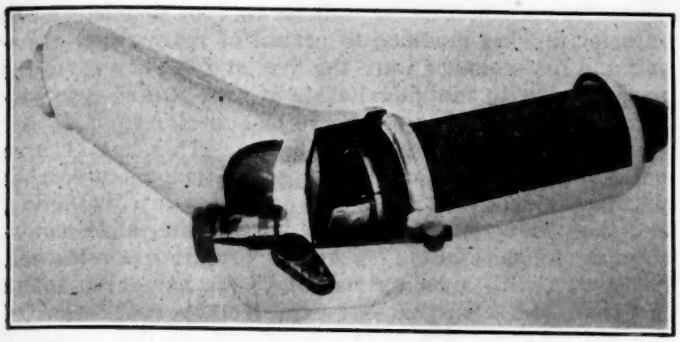

Fig. 14—Compressed-Felt Oil-Filter
This Hall-Scott Filter Is Said To Remove All Water, Dirt and Metal Particles and To Reduce the Oil Dilution

enclosed within the rocker-arm cover and operates in an oil-bath that reduces wear to the minimum.

Vibration

Vibration has been the bugbear of closed-body automobiles, but in the Fageol safety-coach it has been reduced very materially. This has been accomplished by reducing the vibration in the engine until it is not noticeable. The rotating parts are balanced both statically and dynamically. Reciprocating parts are accurately machined to come within weight limits of plus or minus 1/8 oz. for the connecting-rod and piston assembly. The crankshaft and crankcase are extremely rigid, further reducing vibration. Identically machined combustion-chambers and an intake-manifold system designed for uniform gas-distribution ensure uniformity of power impulse.

Unit mounting of the radiator and the transmission on the engine increases the mass and tends to reduce the amplitude of the power-impulse vibration. Mounting the engine on Thermoid pads and flexible supports tends to prevent periodic vibration in the chassis.

We feel that practically no development has taken place during the last few years covering transmissions and clutches. While the present-day transmission and clutch are adequate and satisfactory for passenger-car work and fairly satisfactory for motor-truck work, the conditions of motorcoach service require a greatly increased number of clutch engagements and gearshifts per day, sometimes running as high as 4000 in urban operation. We are very hopeful that during the next few years the engineering fraternity will devote sufficient study to this important subject to really build something that will relieve this situation. The ideal would of course be a combination clutch and transmission with which the loads could be picked-up without jerk or jar and changing from one gear to another would not necessitate the present disengagement of power and intervening elapsed time intervals.

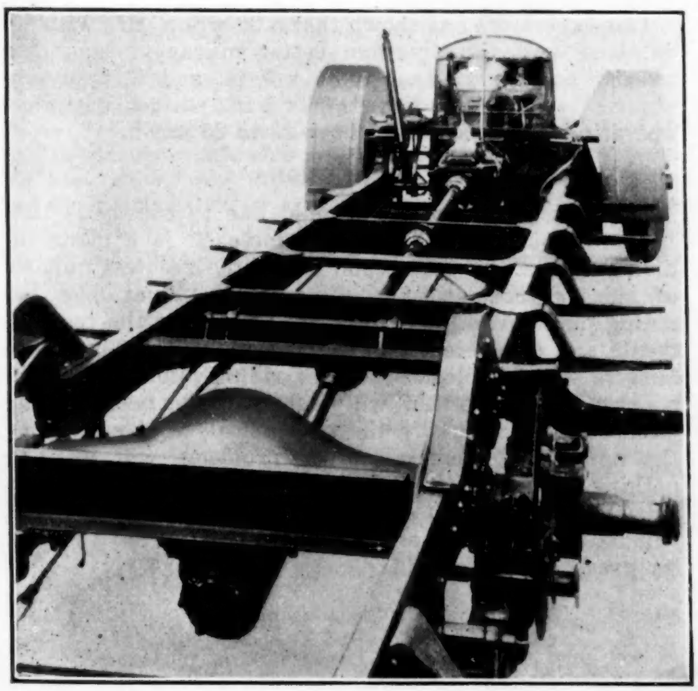

Fig. 15—Safety-Coach Chassis Assembly
The Drive-Shaft to the Underslung Worm-Drive Is in Three Short Sections Coupled by Heavy Universal-Joints and Is Held in Place by Self-Aligning Ball Bearings

Under the circumstances, we have adopted what we believe to be the most satisfactory arrangement available today. This is a multiple dry-disc clutch having a large

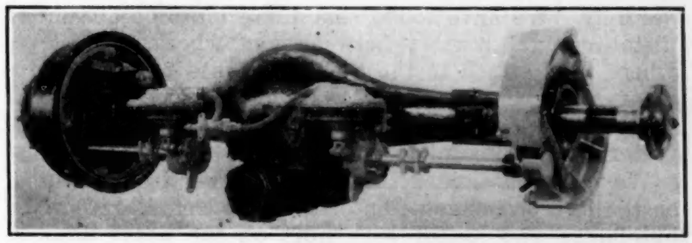

Fig. 16—Rear-Axle and Brake Assembly
Unlined Cast-Steel Brake-Shoes Engage High-Carbon Cast-Steel Drums and Can Be Operated Either by Compressed Air or Manually

number of heavy molded asbestos-fiber plates driving unlined steel-plates, in combination with a four-speed transmission of the strongest construction on the market. These are mounted as a unit with the engine, which facilitates gearshifting, due to the light weight and reduced momentum of the short clutch-shaft parts as compared with the same parts necessary for a transmission mounted amidships.

Drive-shafts of the conventional passenger-car design, but built sufficiently heavy to withstand the increased wear-and-tear, have proved very satisfactory. To make the vehicle operate smoothly and to increase the life of universal-joints, as well as to eliminate the danger of the drive-shafts' whipping-out, it has been found advisable to cut our drive-shafts into three sections, limiting the maximum length of each to 48 in. (See Fig. 15).

Brakes

The development of satisfactory brakes has been one of the most difficult problems, and we consider it as yet far from solved. We believe that ultimately all motorcoaches will be equipped with power-brakes, and we shall not be at all surprised if this is compelled in many places by special legislation within the next 5 years. Owing to the apparent inability to control the consistency or the coefficient of friction of fabric lining, we, in conjunction with the Westinghouse Air-Brake Co., have spent considerable time and money in developing the metal-to-metal-type brake; and, while our problems have been many and difficult, we have made real progress and are much encouraged with the possibilities of this type of brake. Experience has shown that high-carbon-steel shoe-liners, approximately from 0.60 to 0.75 per cent carbon, working against drum-liners of 0.10 to 0.20 per cent carbon, have given the best results, and with this type of material we are able to get from 30,000 to 40,000

miles, in the most severe service, or approximately 300,000 stops, without relining. Highly satisfactory results have also been obtained by using a high-carbon cast-steel drum of approximately 0.60 per cent carbon, working against this a cast-steel shoe of approximately 0.40 per cent carbon, the latter being hinged or balanced as shown in Fig. 16. Cast shoes and drums of this type can be made so that fully ½-in. of wear can be taken from both the shoe and the drum, and experimental vehicles operating in urban traffic, with eight or nine stops per mile, indicate a wear on the shoes of about 0.005 in. per 1000 miles, which indicates a safe life of 50,000 miles, or 400,000 stops for the life of a shoe; and it is indicated that the drums will probably render 100,000 miles of satisfactory service.

Pressed-steel taper-disc wheels are now standard on practically all makes of motorcoach. As most of the motorcoaches built have dual wheels, the use of this type allows of ready interchangeability between all front and rear wheels. These wheels must be bolted on very securely. We have found that there must be absolutely metal-to-metal contact between the wheels themselves where they attach to the hub when used as dual equipment; otherwise they will work loose. Even a coat of paint on the contracting areas of the discs makes satisfactory mounting almost impossible.

We use studs locked in the hubs either by dowel-pins on the lighter construction or inserted clear through the hub-flange and locked with nuts on the heavy brakes. The wheel nuts and nut-ends on the studs are threaded right-hand on the right side of the motorcoach and left-hand on the left side, as a precautionary measure.

Steering-Gear

The variable-pitch-worm cam-and-lever-type steering-gear seems to be satisfactory. However, we feel that there is considerable room for improvement by the steering-gear manufacturers in the design of control levers and mechanism, as to date most of these are far from heavy or sturdy enough for the work imposed.

To attract the maximum patronage, a motorcoach must be so finished that it can be kept spick-and-span at all times with the minimum of time expended. We found that paint and varnish did not retain its original character sufficiently long and that to repaint by that process required from 10 to 21 days as the minimum, depending on the conditions and the quality of job required by the operator.

Our first coach, the Silver Fox, as well as every one built since was finished in pyroxalin enamel, which is similiar to the numerous celluloid-base finishes now being marketed under a number of trade-names and coming into use very extensively in the finishing of passenger automobiles. Pyroxalin finish improves with repeated dry-cleanings and can be completely done over in from 2 to 4 days.

The private automobile has established the riding requirements of the public, and it is apparent that the motorcoach, to attract maximum patronage, must equal or exceed the comfort and luxury to which the public has become accustomed in their experience with other means of transportation. Limousine-type upholstery and interior finishes modified to permit of more ready cleaning and maintenance were the first step. Then came the parlor-car, with individual seats of over-stuffed-type construction, this having proved to be superior to any other type of vehicle for intercity service. This has been so noticeable that our orders for sedan-type motorcoaches with individual side-doors for each seat are dwindling, and the production of individual-seat center-aisle motorcoaches, finished either in velour or fine grain-leather, has grown with amazing rapidity. We have even found in urban operation that our experience parallels that of the electric railways in showing definite increases of patronage as seats have been developed which, while permitting a sufficient number of passengers to allow profitable operation, came closer and closer to the automobile type.

Weight

Practical experience is rapidly showing all of us that we have really reached and exceeded practical weight-limits, so that in future designing of frames, axles, springs, engines, transmissions, bodies, and all other parts, the weight factor must be given serious consideration, so that we may retain and if possible increase present passenger-carrying capacities. We have already exceeded the practical weight-limits on present-day pneumatic-tire design. Experience has taught us that the 24-in.-base tire is really the minimum size for practical use, because with any smaller base it is practically impossible to install brake-drums of sufficient size and still have enough clearance between the brake-drums and tires to permit proper cooling.

Experience has demonstrated that tires which do not suffer from excessive brake-drum heat will give twice the mileage in the same service that tires which are subject to the damage of overheating from the brake-drums will give. Since tire costs at present high prices must be reckoned at from 2 to as high as 3½ cents per mile, this alone prohibits serious consideration of the 20-in. base tire.

Our experience has shown that a 36 x 6-in. tire with 24-in. base will actually give better mileage, even when greatly overloaded, than a 34 x 7 in. and in many instances better service than a 36 x 8 in., particularly when operating speeds average above 20 to 25 m.p.h.

Conclusion

I repeat, the message I would like to convey is that the greatest problem of the motorcoach is a merchandising problem, to create and to sell the greatest number of rides at the lowest possible cost. "What does the riding public want, and what will best meet the requirements and convenience of the passengers?" Therefore, analyze your problem, study the riding public and build a practical vehicle that will best meet the needs of the public, and incidentally the mechanical requirements of the operator. Then, all other problems will melt to nothing; because, if the operator does not sell enough rides, his entire cause will finally be lost; his efforts will be futile; and the motorcoach will not have served its great economic field.

BRAKES ON MOTORCOACHES[1]

THE four-wheel brake has so far been found of little advantage on heavy vehicles, both because their slower speed lessens the tendency to skid and because the greater proportion of weight on the rear wheels makes rear-wheel brakes correspondingly more effective. Developments in heavy vehicle brakes, therefore, have centered chiefly about increasing the effectiveness of rear-wheel and shaft types of brake, in both of which great progress has been made. In general, improvements have been made in the stopping ability, durability of linings, rapidity of heat radiation, reliability, and serviceability of these brakes. In addition great progress has been made in auxiliary sources of braking energy, such as the development of automotive airbrakes and vacuum booster-mechanisms.

Even the heaviest and slowest of vehicles have been favored, namely, tractors and trailers and big six-wheel trucks, such as have become so popular on the Pacific coast. Trailers are often fitted with brakes applied either by their own inertia against the drawbar, by auxiliary hand-control or by air. Six-wheel trucks are commonly provided with brakes on all four rear wheels.

While not so spectacular as some of the other developments, much has been accomplished in some of the lesser details of brake equipment which have contributed materially to greater effectiveness. Brake-linings, for example, have been improved so that while maintaining a satisfactory coefficient of friction they are at the same time longer-lived and less affected by heat. Some very interesting results have been achieved with metal-to-metal brakes in connection with pneumatic actuation whereby much greater durability and resistance to heat have been secured at a considerable sacrifice in the coefficient of friction, the latter being compensated for by the use of greater pressure for application which is made possible by air actuation. Great strides have been made in the improvement of brake-drums, both as to rigidity to resist distortion and better radiation of heat. Brakes are being enclosed better. The layout of brake-levers and rods has been more skilfully carried out so that the action of the springs, particularly in Hotchkiss drives, has been practically nullified in its effect on the brakes. Brake-levers and pedals have been improved in design to give the driver an opportunity to apply his effort more effectively. Important advances have been made in the detail design of brakeshoes, the disposition of brake anchor-pins and in brake actuating cams. Much needed improvement has been effected in the ease and accuracy of brake adjustment.

The maximum tolerable rate of deceleration is determined by what an average human being can endure, since ordinarily the structure of a motor vehicle is capable of withstanding more than a person. This is somewhat subject to controversy, but hardly anyone would place it much beyond 15 ft. per sec. per sec.

Assuming a vehicle whose gross weight is 5000 lb. moving at 40 m.p.h. along a level stretch of cement-concrete highway that is smooth and dry, with four-wheel brakes, all equally effective and new, and non-skid tires, we find that at 15 ft. per sec. per sec. deceleration it will require 106 ft. and a duration of 4 sec. to stop. This is the extreme brake effectiveness that can be considered bearable. It is possible of attainment, by any means we now know of, only on very light vehicles. It is far beyond the requirements of Scotland Yard, which are based on the formula $V^2/10$, in which V is the velocity in miles per hour. This formula works out to 10.8 ft. per sec. per sec. deceleration.

Problem of Heavy Vehicles

In the case of heavier vehicles, such as motorcoaches, on which most of the load of necessity is on the rear wheels for ease of steering, a rate of deceleration of 15 ft. per sec. per sec. is impracticable at the present time. The lighter vehicle may employ front-wheel brakes to advantage, but the heavier motorcoach has very little to gain from their use. In the first place, the greater part of the weight being on the rear wheels, they must be called upon to accomplish most of the retardation. In the second place, the effectiveness of front-wheel brakes must be purposely limited to avoid locking them, for, if the front wheels lock, control of direction will be lost and this might easily prove more disastrous than inadequate braking.

In making the rear-wheel brakes sufficiently effective to dissipate the radically greater amount of kinetic energy represented by the heavier vehicle operating at equivalent speeds, the motorcoach designer is confronted by a number of possibilities, most of which prove impractical upon examination, test and analysis. The variables whose increase will cause an increase in brake effectiveness are, principally, ratio of brake-drum to rear-wheel diameter, brake-pedal leverage, brake-pedal pressure, leverage through brake connections, leverage of brake cam, and coefficient of friction between the brake-drum and the braking surface or lining.

Propeller-shaft brakes, because of the advantage secured through the reduction in the driving gears, afford the equivalent of a great increase of effective brake-drum to rear-wheel diameter ratio; but structural limitations do not permit their areas to be increased adequately.

The coefficient of friction between the brake-drum and the brake-lining is already at the maximum compatible with reasonable heat-resistance in all conventional types of asbestos-fabric lining. Metal-to-metal friction is essentially lower than that of brake-linings. Some important and interesting developments are being made with an entirely new type of brake facing material that promises a greater coefficient of friction with greater heat-resistance, but this development is so far incomplete.

A measure of the magnitude of the braking problem involved in heavy vehicles operating at high speeds is afforded by the following comparison between a 5000-lb. passenger car and a 15,000-lb. motorcoach, both operating at 40 m.p.h. and both stopped at a rate of deceleration that may be considered the maximum to be expected of either at present:

Type of Vehicle	Passenger Car	Motorcoach
Gross Weight, lb.	5,000	15,000
Weight Distribution	40–60	35–65
Brake Location	Rear-Wheel Drums	Rear-Wheel Drums
Wheel Diameter, in.	32	34
Brake-Drum Diameter, in.	18	18
Brake-Drum Width, in.	2½	5
Speed from Which Stop Is To Be Made, m.p.h.	40	40
Coefficient of Adhesion between Tire and Road	0.65	0.60
Rate of Deceleration, ft. per sec. per sec.	12.6	12.6
Stopping Distance, ft.	137	137
Kinetic Energy Stored, ft-lb.	267,000	801,000
Maximum Braking-Force, lb.		
At Ground	1,950	5,850
At Drum	3,460	11,060
Pressure To Be Applied to Brake-Drum, lb. per sq. in.	163	615

From this it will be seen that to stop the motorcoach requires that 3.2 times the energy necessary in the case of the passenger car be dissipated. To do this with equal heat per square inch would require a brakeshoe 3.2 times as wide as that on the passenger car, or 8 in. wide, which is unattainable at the present time. The 5-in. brake, which is about the practical maximum at present, must therefore contend with a 38-per cent increase in heat generation. Here lies its principal limitation.

[1] From an address delivered by M. C. Horine at the annual meeting of the National Highway Traffic Association at New York City on April 30, 1926. The author is sales promotion engineer with the International Motor Co., New York City.

Human Limitations

The maximum pedal-pressure that we can hope to utilize is about 200 lb. for an adult such as we may reasonably expect to find at the wheel of a heavy vehicle; that on the hand-lever being about 100 lb. The maximum pedal-throw is about 5 in. The minimum brake-clearance, that is the clearance between the lining and the drum, is 1/8 in. The brake-lining coefficient of friction cannot be depended upon to exceed 0.27 when reasonable durability and heat-resistance are to be expected. The coefficient of friction between the tire and the road can safely be taken at 0.60 for fair conditions. Within these limitations, then, further improvement must be confined. Developing any one feature of brake design will not necessarily increase brake effectiveness, because of the limitations imposed by other factors. Within these limitations, however, certain things, heretofore unattained, are possible. By ideal placement of pedals and their fulcrums in relation to the driver's position, it is possible to secure the maximum pedal-pressure. By employing frictionless joints it is possible to transmit nearly all of this energy to the brakes. By a scientific layout of rods and connections it is possible to apply this energy so that it will be of maximum effectiveness at the time of brake contact and unaffected by spring action. By correct proportioning of leverages, we can secure the maximum pressure usable on the brakes, although still preserving sufficient brakeshoe clearance throughout a considerable range of progressive wear of lining material. By constructing all parts of the brake in strict conformity with good engineering practice, correct alignment, concentricity and rigidity can be preserved sufficiently to prevent loss of the advantage thus gained.

Attempts to regulate design of brakes will retard rather than advance development, thereby lessening instead of increasing safety. The manufacturer can be depended upon, if only for the protection of his own selfish interests, to prosecute the further perfection of automotive brakes more vigorously if unmolested than regulative pressure could ever make him do.

TROUBLES WITH HEADLIGHTING EQUIPMENT

(*Concluded from p.* 32)

the smallest spot. The diameter of this spot is shown in Table 2, column *B*. Then the card was removed, the diameter of the whole spot was measured; the results are tabulated in Table 2, column *C*. Next, the 4-in. circular blank was placed immediately in front of the reflector and the beam from the outer zone was focused and measured, the results being presented in Table 2, column *D*. Column *E* of Table 2 shows the diameter of the spot from the whole reflector when the 4-in. circular blank was removed.

All these measurements are of course relative and are less than would be shown in a laboratory test. One of the most interesting things about these measurements is shown in Table 2, column *F*, in which a tabulation is made of the change in filament position from that for greatest concentration of the beam from the central zone to that for greatest concentration of the beam from the outer zone. In the case of lamps 4*a*, 4*b* and 4*c*, a very considerable difference in the focal position for the front part of the reflector and that for the rear part of the reflector is noted. These results are so obviously indicative of improper construction that no further comment seems to be necessary.

Conclusions

The first step toward the improvement in automobile headlighting-conditions should be the correction of inferior head-lamp equipment now being installed and an effort to simplify, to the greatest possible extent consistent with performance, the construction and adjustment of head-lamps. The correction of inferior headlamp equipment necessitates above all a better understanding of the headlighting problem by the automobile-company officials who determine the policies of the company. Common sense should be used in the design and construction of the lamp so that difficulties shall not be encountered in ordinary usage from improper construction of the several details, many of which are given in this paper.

Immediate attention should be given to two outstanding difficulties: First, the variation from designed optical characteristics by reason of improperly shaped reflectors and improperly located light-sources; second, the insecure mounting of head-lamps which results from insufficient grip in the mounting bearing, improper design or construction of the lamp-mounting support and improper design or construction of the parts to which the lamp-mounting support is attached. In connection with the first difficulty I cannot stress too strongly the necessity for designing lamps so that they do not have an excessively high maximum beam-intensity. The maximum beam-intensity should be near the top of the beam and from this point or zone of maximum intensity the beam should shade-off gradually without contrast.

Most members of the public with which the administrator has to deal have no good understanding of the fundamental principles of light projection and, therefore, they must not be given lamps which are so complicated that they cannot be adjusted by following the fewest possible number of simple rules. A good example of such a complication is the use of more than one focusing adjustment. No description of the method of adjusting head-lamps equipped with multiple focusing-adjustments that can be understood easily and followed by the average motorist has yet come to my attention. Rather, every effort should be made toward the development of units that require no focusing adjustment. When the instructions for adjustment of head-lamps issued by the motor-vehicle administrator can read simply: "Aim the lamp so that the beam is confined below the level of the lamp centers," a long step will have been made toward the solution of the problem.

TABLE 2—MEASUREMENT, IN INCHES, OF REFLECTOR ACCURACY WITH SCREEN 25 FT. DISTANT AND FOCUS ADJUSTED FOR SMALLEST CIRCLE

Lamp	A	B	C	D	E	F
3*a*	22	22	24½	19	22	1/64 back
3*b*	24	23	24	20½	24	None
4*a*	..	35	57	35	77	1/8 ahead
4*b*	41	28	45	31	54	3/32 ahead
4*c*	34	32	39	21	56	5/64 ahead
5*a*	28	22½	32	20½	30	1/32 ahead
5*b*	29	24	31	21	30	1/32 ahead

Balloon Tires for Heavy Vehicles

By J. E. HALE[1]

CLEVELAND SECTION PAPER *Illustrated with* CHARTS AND PHOTOGRAPHS

ABSTRACT

MOST of the riding-comfort obtainable in motorcoaches at present is due to the effect produced by a combination of the heavy bodies with suitable spring design, supplemented by such devices as cane chairs having spiral-spring legs and comfortable cushions. As additional ease of riding can be obtained by the use of tires designed for lower inflation-pressures, an insistent demand for their adaptation to motorcoaches has arisen among the operators. Poor pavements in the city, the necessity for running off the pavement frequently when passing other vehicles in intercity service and the fact that some passengers during rush-hours are obliged to stand, make the use of high-pressure tires objectionable, and tire manufacturers have endeavored to meet the demand for greater comfort by reducing the pressure of the tire to approximately 45 or 50 lb. per sq. in. and offering a choice of four tire sizes instead of three.

In general, the development of low-pressure tires for motorcoaches is said to be similar to that of their recent development for passenger cars. Because of a desire to maintain the gear-ratios at present in use, the 20-in. wheel rim has been commonly adopted. The various difficulties encountered with tires of the balloon type, due largely to lack of sufficient space, which causes insufficient ventilation and excessive heating, are severally considered, as are also the effects on braking, fuel consumption, acceleration, and the like. The deleterious effects resulting from under-inflation are said to be as serious as those from overloading, and tables are given to indicate the mileage expectancy with tires of various sizes when subjected to different loads. Divers precautionary measures are suggested with a view to reducing the tire-mile cost.

BALLOON tires for motorcoach and truck use have been developed because of the insistent demands of operators for tires that could be used with a lower standard of air-pressure than has been recommended in the past. The greater number of pneumatic tires used on trucks and motorcoaches require from 90 to 100-lb. inflation-pressure, which makes a hard cushioning-medium.

Although it is true that a high-pressure tire absorbs many road inequalities, most of the riding-comfort of motorcoaches is due to a combination of the heavy bodies and the spring design, so worked out that the combination produces a fairly good effect. Then, too, to increase the riding-comfort, body-builders have resorted to cane chairs with spiral-spring legs and comfortable cushions to overcome the jars of the road and provide comfortable riding. But reducing the inflation-pressure gives ease of riding additional to that which can be obtained by these methods.

In city service, where the pavements are frequently poor, and during rush-hours, when passengers are obliged to stand, hard-riding vehicles are very tiresome and objectionable. Likewise, in intercity work, where motorcoaches run at high speed, and in passing vehicles going in the opposite direction, when it is often necessary to run off the paved surface and hit chuck-holes or uneven strips of pavement, tires too firm or hard will give very unpleasant riding.

Some tire manufacturers believe that the pressure can be lowered and tires for motorcoach service can be designed to run at pressures of from 45 to 50 lb. per sq. in. To visualize the comparison of balloon and high-pressure tires, Fig. 1 makes a comparison of the difference in cross-section widths. High-pressure tires are now made in 5, 6 and 7-in. cross-sections, whereas in motorcoach balloon tires, it is better to produce four sizes instead of three, because these will give a better choice, depending on the load to be carried, without too great intervals between them, and so the 6.75, 7.50, 8.25 and 9.00-in. cross-sections have been chosen.

The problem of balloon tires for motorcoaches, as regards the tires themselves, has been similar to that of balloon tires for passenger cars; consequently, they have been worked out along the same principles and design.

FIG. 1—COMPARISON OF CROSS-SECTION WIDTHS OF BALLOON AND HIGH-PRESSURE TIRES

High-Pressure Tires Are Offered in 5, 6 and 7-In. Cross-Sections, whereas Motorcoach Balloon Tires Are Made in Four Sizes, 6.75, 7.50, 8.25, and 9.00 In., To Give a Better Selection

[1] M.S.A.E.—Manager of development department, Firestone Tire & Rubber Co., Akron, Ohio.

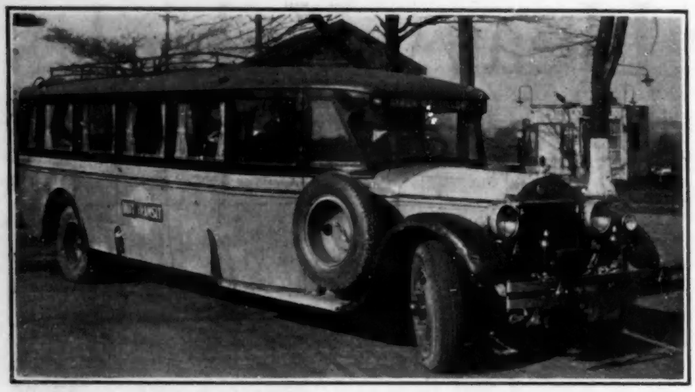

FIG. 2—TYPICAL BALLOON-TIRE INSTALLATION
Intercity Motorcoach Running between Akron and Massillon, Ohio

The motorcoach balloon-tire, with the use of low-pressure air, will give a larger area of contact because of the low pressure and, with this larger area of contact, the tire necessarily must have a large enough cross-section so that, when it deflects or flattens out under the load, the percentage of deflection will not be too great or beyond the point at which long and satisfactory tire-mileage will be secured.

We intend to use thinner sidewalls and suitable tread so that the tires will deliver long mileages as well as render a greater degree of riding-comfort. The sidewalls, however, will not be as thin as those of passenger-car balloon tires, but will be as thin in proportion as those of the tires they replace, there being six plies in the two smaller sizes and eight plies in those that are larger.

The new tires are sufficiently developed so that a considerable number of them are in use. Figs. 2, 3 and 4 show some of the installations that have been made.

Table 1 shows in detail how the motorcoach-balloon line-up has been worked out, beginning with the 6.75-in. cross-section with a maximum load of 1700 lb., the 7.50-in. at 2100 lb., the 8.25-in. at 2500 lb., and the 9.00-in. at 3000 lb., all being run at an inflation-pressure of from 45 to 50 lb. per sq. in. The smaller sizes have been designed to fit the standard 32 x 6-in. truck rim, while all the others have been worked out for use on the standard 34 x 7-in. rim. The center spacing between the wheels has been increased to take care of the larger cross-section of the tire and also the increased bulge resulting from the load on the lower-air-pressure tire.

TABLE 1—HEAVY-DUTY BALLOON-TIRE LINE-UP

Nominal Size, In.	Load, Lb.	Inflation-Pressure, Lb. per Sq. In.	Size of Truck Rim, In.	Dual Center Spacing, In.	Sectional Diameter, In.	Over-All Diameter, In.	Rolling Radius, In.
6.75 20	1,700	50	6	8 13/16	7.04	34.27	15.84
7.50 20	2,100	50	6	8 13/16	7.48	35.33	16.32
8.25 20	2,500	50	7	10 1/16	8.44	36.73	16.85
8.25 22	2,500	50	7	10 1/16	8.44	38.73	17.89
9.00 20	3,000	50	7	10 1/2	9.02	38.18	17.47
9.00 22	3,000	50	7	10 1/2	9.02	40.18	18.51

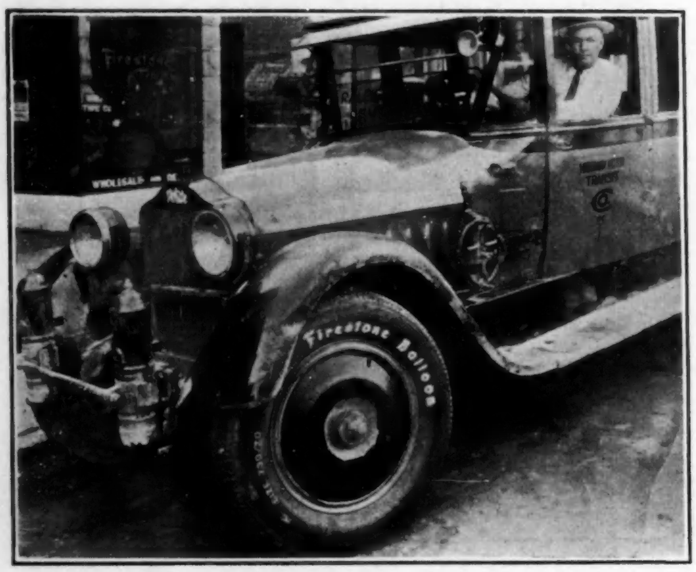

FIG. 3—ANOTHER INSTALLATION OF BALLOON TIRES ON INTERCITY MOTORCOACHES
This Line Runs from Zanesville to Columbus, Ohio

EFFECTS OF LARGER CROSS-SECTION AND DUAL WHEELS

Certain effects in motorcoach design have appeared with the use of balloon tires that we have had to work out due to the larger cross-section and the space consumed by the dual wheel in the wheel housing. It seemed desirable to resort to the 20 and 22-in. wheels to provide for the increased space taken by the two tires in dual formation, so as not to upset the present gear-ratios. In other words, if we had adopted 24-in. wheels, the tires would be so large that it would be impossible to install them on motorcoaches as at present designed and would upset the gear-ratios; consequently, we have disregarded the 24-in. and have adopted the smaller wheel.

The loaded radius of the motorcoach tire is about the same as that of the high-pressure tire that it replaces. This is shown in the column headed Axle to Ground Heights, in Tables 1 and 2. A good example is shown in Fig. 5, comparing the 32 x 6-in. high-pressure tire with the 8.25/20-in. balloon tire and, although the balloon tire is slightly greater in over-all diameter, the deflection of the balloon tire is almost twice that of the high-pressure tire, which results in a rolling diameter that is about the same in both cases. In other words, the motorcoach balloon-tire flattens out sufficiently so that the axle of the vehicle is about the same height from the ground as it is with the high-pressure tire. With motorcoaches of new design using this new tire, the wheel housing must be higher and wider to take care of the tire of larger cross-section, and the frame must be narrowed sufficiently to take care of the installation for, in the dual combination, the over-all width of the tires is considerably greater, as is shown in Fig. 5.

In this figure, a common center-line has been taken between the two pairs of wheels. To carry out the design, it was necessary to move the springs in slightly and, consequently, to make a narrower frame, the difference being 2 in. On the other hand, you will note that the over-all, or track, of the wheels has been increased by approximately 3/8 in.

Fig. 4—White Motorcoach Equipped with 7.30/20-In. Balloon Tires

Results of Insufficient Clearance

In Fig. 6 is shown the very small clearance between the brake drum and the rim. The reason is that wheel and tire designers favor the smaller wheel, whereas motorcoach designers naturally desire to use as large a brake drum as possible. With the enormous amount of energy that must be dissipated in the form of heat during operation, we find that brake drums become hot and, in most cases, do not have sufficient ventilation. The heat is not allowed to radiate because, on the outside, the quarters are close and, on the inside, there is generally a dust-shield, which of course tends to hold the heat. Consequently, a large amount of heat is transferred to the tires. In some cases sufficient heat has been created to have a very disastrous effect on the rubber in the beads of the tire and on the tubes. Instances have occurred in which the rubber in the beads softened to such an extent that the tire failed because the bead wire pulled out of the fabric, or the "tie-in", as it is generally known.

I have known of wheels that became so hot that the nuts fastening the wheels to the hubs could not be handled without gloves, and the rim became so hot that the garage man could not handle it in making the tire change. I suspect that dragging brakes are the cause of a large part of the trouble, that is, not all the heat comes from the dissipation of energy in stopping the vehicle, but the clearance is so small, in the brake and brake-drum combination, that the brakes actually drag.

Adaptability to Motorcoach Service

To give an idea of the service in which and of the type of motorcoach on which the different sizes of balloon tires will be used: the 6.75-in. tires will be used as singles on motorcoaches carrying 12 or fewer passengers or possibly as duals on a heavier vehicle; the 7.50-in. tires will be used as singles on motorcoaches carrying as

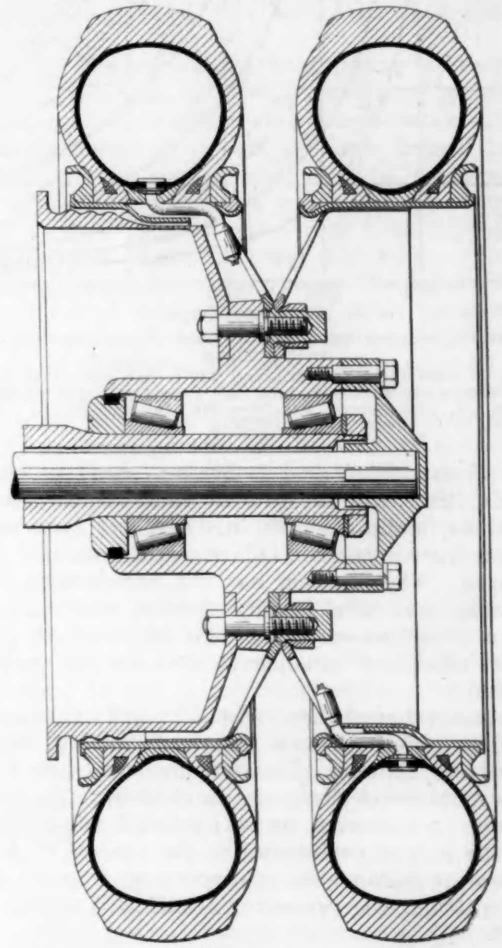

Fig. 6—Diagram Showing the Very Small Clearance between the Brake Drum and the Rim of the 32 x 6-In. Dual Wheel

Insufficient Ventilation Prevents the Enormous Amount of Heat Generated from Being Dissipated, So That the Brake Drums Become Hot and the Heat Is Transferred to the Tires, with Disastrous Effect on the Rubber in the Beads and the Tubes

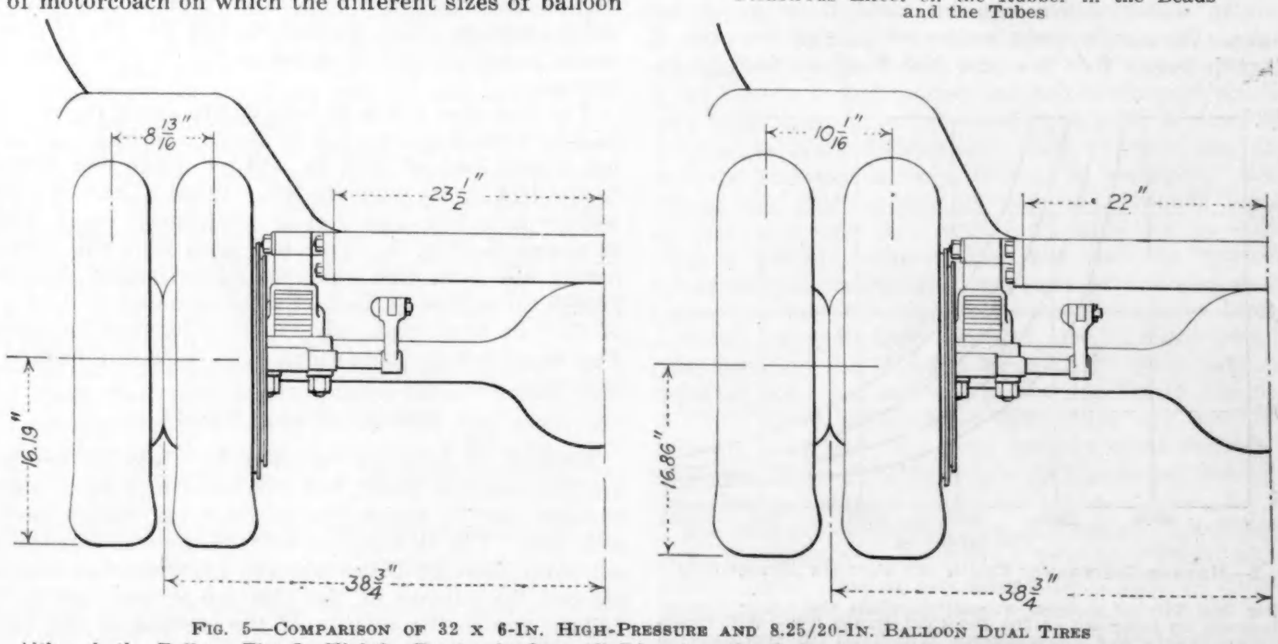

Fig. 5—Comparison of 32 x 6-In. High-Pressure and 8.25/20-In. Balloon Dual Tires

Although the Balloon Tire Is Slightly Greater in Over-All Diameter, the Deflection of the Balloon Tire Is Almost Twice That of the High-Pressure Tire, so That the Rolling Diameter Is about the Same in Both Cases

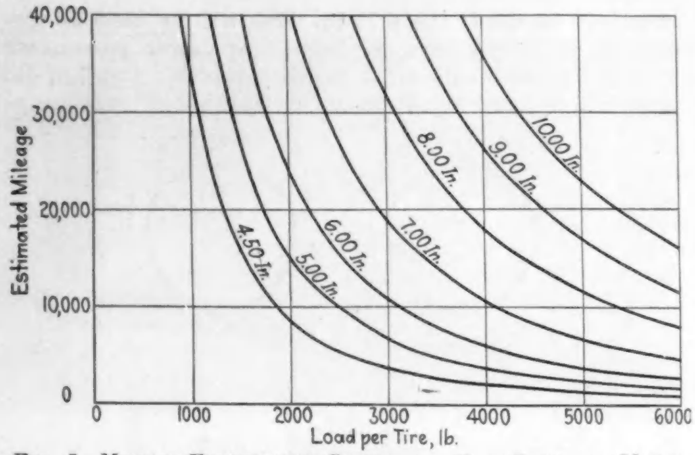

FIG. 7—MILEAGE-EXPECTANCY CHART FOR HIGH-PRESSURE MOTORCOACH TIRES

This Study Shows How the Mileage That Can Be Obtained from a Tire of Any Size Is Affected by the Load Imposed on the Tire. The Effect of Insufficient Air-Pressure Is Similar to That of Overloading

many as 18 passengers and as duals on heavier vehicles; the 8.25-in. tires will be used as duals on 25-passenger motorcoaches, while the 9.00-in. tires will take care of the 30-passenger vehicles. Of course, this is only a general opinion. The problem has not been solved for, in many cases, especially in city service where standees compose a great percentage of the overload, it is hard to tell just what sizes must be worked out for conditions of this kind.

Low-pressure-tire design for motorcoach operation will have a direct effect on axle stresses, steering, braking, ridability, and control. The low-pressure tire will be helpful to motorcoach designers in reducing axle stresses due to impact; moreover, as was pointed out in the beginning, the lack of cushioning in the case of 90 to 100-lb. inflation-pressure produces very severe impacts on the axle, and cutting this pressure in half will surely be of advantage.

Without question lower-pressure tires steer harder than high-pressure tires. This problem arose when balloon tires were applied to passenger cars and, although it seemed an obstacle at the beginning, it has been worked out very satisfactorily. I feel that their application to motorcoaches can be handled in a similar manner. We simply must recognize that as the area of contact between the tire and the road surface is increased, due to the larger cross-section and the lower air-pressure used, it is natural to expect harder steering.

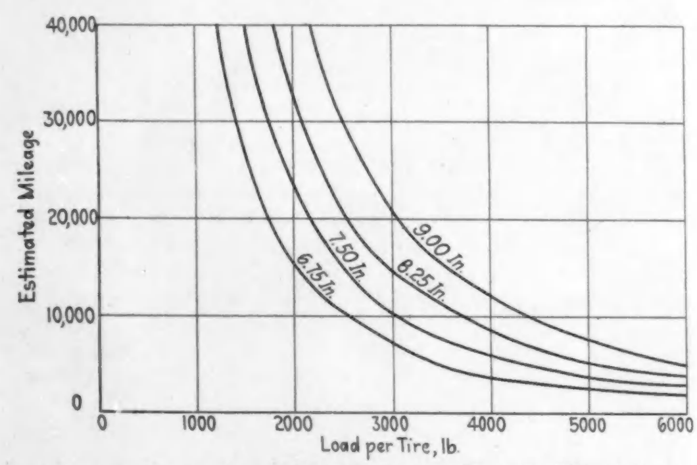

FIG. 8—MILEAGE-EXPECTANCY CHART FOR BALLOON MOTORCOACH TIRES

Running One Tire of a Dual Formation while the Other One Is Flat Imposes an Overload of 100 Per Cent on the Tire, Will Cause Premature Failure and Consequently Will Tend To Increase the Tire-Mile Cost to the Operator

The same area of contact that will increase the steering resistance will likewise increase the braking effect. Fuel consumption will be practically the same, if test experience, as worked out on passenger-car tires, can be used as a criterion. Likewise, the pick-up or acceleration of the vehicle is not affected to a noticeable degree. Practical application of balloon tires has worked out very satisfactorily on both intercity and city motorcoaches. In other words, once the tires have been fitted and are running, no complications will arise. As the tires become perfected, they may be expected to give a mileage commensurate with that of the high-pressure tire and at as low a tire-mile cost.

EVILS OF OVERLOADING

One point I wish to emphasize forcefully is the evils of overloading. The tire industry has conducted a constant campaign to get manufacturers and the public to use the proper sizes of tire to carry the loads and sufficient air-pressure to support the loads. With the use of balloon tires on motorcoaches, this must be brought more strongly to the attention of manufacturers and operators, because with balloon tires the air losses will be approximately 100 per cent greater than with the high-pressure tires, and for this reason more attention must be given to the inflation of the tire. The effect of underinflation is nearly as bad as that of overloading and, with either one or the other, the tire deflects beyond the allowable percentage recognized by the industry and affects the tire to such a degree as to bring about premature wear or failure.

Fig. 7 is known as a mileage-expectancy chart. A study will show that the mileage obtainable from any size of tire is affected by the load imposed upon the tire. Insufficient air-pressure has an effect similar to overloading. The operator, therefore, should do everything possible in the way of lining up the wheels so that the valves will be accessible for inflating the tires. We are dealing with a commercial proposition, which is governed by pressure and comfort. The motorcoach operator's profits are largely affected by tire cost and can be largely governed by the attention given to the tires, because tire cost is a very large item in the total operating-expense. The tire cost during the life of a motorcoach is approximately equal to the original cost of the vehicle.

The fact that a tire is designed to carry the maximum load of 2200 lb. is very often discounted, the user assuming that a load of 2800 lb. will not make any difference to the tire or its ultimate life. What a load of 2800 lb. will do to a 6-in. tire that is designed to carry 2200 lb. is shown in Fig. 7. You will note that the curve denoting the 6-in. tire indicates an estimated mileage of 20,000 for a 2200-lb. load. By the same method, if a load of 2800 lb. is carried, only 12,400 miles may be expected. The same relative conditions exist with motorcoach balloon tires.

PRECAUTIONARY MEASURES

Neglect of injuries received by tires in service is another common fault, but careful attention to them is another way by which the operator can reduce the tire-mile cost. The ill effect of cuts on the tire carcass is an old story, but the little cuts and injuries that may have pierced the carcass of the tire are responsible for tire failure due to the rotting of the carcass or the separation of the tread.

Another point to be brought to the operator's attention is that of running one tire of a dual formation while the other one is flat. This feature, of course, appeals to a motorcoach operator in that he is able to continue the run and make the tire change at the terminal, for in this case, if one tire becomes flat, he can rely upon the other one to carry the load. It can be seen that this causes 100-per cent overload on the other tire, will cause premature failure and consequently will tend to increase the tire-mile cost to the operator.

In intercity work where high speed is required and on pavements where the dirt strip is in poor condition, the fact that the outside dual tire usually overhangs the dirt strip and throws all the load on the inside tire, as the vehicles coming from the opposite direction are passed, is also hard on tires and is responsible for considerable trouble.

Front-wheel alignment is another bugaboo to tire service that should be stressed in connection with the other points that must be watched in the effort to reduce the tire-mile cost.

The question is frequently asked: How soon will balloon tires come into use on heavy vehicles? Naturally, I give only my personal opinion, which is that they will come very rapidly; the demand will parallel that of passenger-car balloon tires. My judgment is that the public will force them into use on the motorcoach and that they will come with such rapidity and momentum that they will create a very hard problem because of the many difficult engineering features that will enter into the work of adapting the tires to the vehicle.

The work of changing over a large proportion of motorcoaches that are now running will be difficult on account of small road-clearance, greater over-all width, and too small wheel-housings. The expense of these changes and of the new wheels will reduce the number of existing motorcoaches changed over to balloon tires. I think, however, that the demand from the public for softer tires will react forcefully on motorcoach builders and that they will make the necessary changes; if they do not do so, they will have a hard task in answering their customers.

THE DISCUSSION

A MEMBER:—The question naturally arises, with reference to the use of balloon tires on motorcoaches, what to do in case of a blowout. I understand that some progress has been made with regard to puncture-proof tubes. Has that feature been worked out in a satisfactory manner on motorcoaches?

J. E. HALE:—Blowouts of balloon tires on motorcoaches need not be feared any more than blowouts of other tires. High-pressure tires blow out just as quickly as motorcoach balloon tires. As a matter of fact, blowouts are not very frequent. I do not see that there is any cause for worry from blowouts.

A MEMBER:—I had in mind the question of the motorcoach tipping over in case of a blowout.

MR. HALE:—That problem is no more serious with balloon tires than with high-pressure tires; in fact, not so serious, because the tires are reliable and more dependable and are not subject to premature failures. Our experience with balloon tires on passenger cars indicate the truth of that.

ERNEST WOOLER[2]:—Is there any tendency for balloon tires to shimmy when used on motorcoaches at high speeds?

MR. HALE:—I have heard of only one case and I heard of that since I came here tonight. I am of the opinion that we shall not know the answer or know the facts about shimmying until this equipment has come into widespread use.

DR. H. A. WINKELMAN[3]:—In addition to working on the balloon sizes that have been mentioned by Mr. Hale, we, in conjunction with that program, have experimented with the ovalcord tire in varying sizes from 7 to 12 in. The 12-in. tire is used in place of 6-in. duals and possesses certain advantages. The problem of unequal air-pressure in dual tires is common to both high-pressure and balloon dual tires. A lower air-pressure in one of the duals places an excessive load on the other tire. The outside tire of a dual installation often rides the curb or the dirt strip, throwing the load on one tire or the other. Both these problems are taken care of by the use of a large single tire. The larger contact-area of the single tire reduces the rubber job. The over-all width of 12 in. does not present the housing or spacing problem that is presented by the motorcoach balloon tire. The ovalcord tire is slightly greater in height than the high-pressure tire that it replaces, eliminating the problem of increased tire-height that is present in motorcoach balloon tires.

I. R. RENNER[4]:—As Dr. Winkelman has said, in commenting on another type of low-pressure tire, we are not taking exception to anything that Mr. Hale has said with regard to the motorcoach balloon tire. To make lower pressure possible, the area of contact must be increased. We find, however, that a difference of opinion exists as to how this increased area of contact should be obtained. Some favor single tires throughout, while others favor duals for the rear wheels.

We will grant that, when single tires are used, two spares, one of each size, are necessary; that a change must be made immediately in case of puncture or failure; and that greater loss is incurred if the tire is run deflated. On the other hand, with single tires all around, all the tires are working; inflation is less difficult; the over-all width is increased; and certain strains are materially reduced.

With dual tires, the same size of tire can be used throughout, one spare will suffice and, in case of puncture of one of a pair of rear-wheel tires, the motorcoach can continue, although this is expensive at times, especially if the vehicle is well loaded, for one tire cannot stand up very long under the increased load. With dual tires, inflation is more difficult and, under certain conditions, uniform pressure is very difficult to maintain. So, we should say that arguments can be advanced for and against both the dual and the single-tire equipment. This is not only our opinion but also the opinion of motorcoach engineers and operators with whom we have come into contact. For this reason, we have been experimenting with both types of tire, the one you have seen here tonight, and the large single 12-in. tire. The question may not be, which one appeals to the manufacturer or to the operator, but which one will best fit into his program. We must bear in mind that all low-pressure heavy-duty tires are still more or less in the experimental stage.

MR. HALE:—Regarding the problem of tire standards and rim diameters, the 8.25-in. tire on a 20-in. wheel is pretty high. The motorcoach balloon tire, as compared with the high-pressure tire, particularly the 32 x 6-in., is considerably higher. Another inch will mean another

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[3] Superintendent of the technical division, tire division, B. F. Goodrich Co., Akron, Ohio.

[4] Development department, B. F. Goodrich Co., Akron, Ohio.

inch on the wheel. I should like to urge any tire company that desires to interject new sizes to hesitate and to investigate the cooling problem and the brake problem very thoroughly before they begin. I have been greatly concerned about the detrimental effect of brakes on tire-beads. In coming into contact with axle builders and brake experts, I believe they will do an excellent piece of work in handling this problem, and it seems a shame to introduce another line of tire sizes without giving the present line a chance.

THE SATURATION-POINT

WHEN will the saturation-point be reached in automobile consumption? Apparently that date lies far in the future. To maintain the present number of cars in this Country requires an annual replacement production of about 3,000,000 cars. The automobile is the most coveted material thing in our civilization today. Every individual is a potential purchaser and, ordinarily speaking, it is merely the question of having the price. With easy terms of payment a surprisingly large number find the price. This situation will continue, and no one can say when or where the point of saturation will be reached. Great as the home market is, in my opinion a still greater market lies beyond our borders in the foreign countries of the world. Already Mexico and South and Central American countries are awake to the great social and economic value of good roads and the automobile. The leaders of thought in those countries are profoundly impressed by the marvelous advancement brought in the United States through those agencies. They desire to imitate our example. They are looking to us for scientific guidance and instruction in road building.

In 1925 the total wholesale value of the cars and trucks produced reached $3,000,000,000, while the wholesale value of parts, accessories and tires amounted to almost another $2,000,000,000. More than 3,200,000 persons obtained their livelihood from this industry in 1925. We may well ask what the economic situation in the United States might have been today had it not been for the vast range of new activities added to the industrial roster of the Nation by this product.

Labor has been employed at high wages. There has been no unemployment, and yet all of the manufacturing industries have had ample labor to meet their requirements. The farms and factories could not profitably have produced more without creating an embarrassing surplus. What would those 3,200,000 people have done for a living in the last few years had they not found employment in this new industry? They could not have been absorbed in the old-established industries. Production in those industries met domestic and foreign demand in full and could not have been expanded. But one answer can be given to the question; wide-spread unemployment would have ensued and the great unprecedented prosperity of which we boast today would never have existed but for the expansion of the automobile industry and the absorption by that industry of what would otherwise have been a surplus of labor.

TOTAL AMOUNT OF RETAIL AUTOMOBILE PAPER AND OUTSTANDING AMOUNT AT GIVEN TIME

Wholesale Value of Cars and Trucks	$3,000,000,000
Dealers' Gross Discount to Cover All Expenses and Net Profit	600,000,000
War Excise Taxes	100,000,000
Freight and Delivery Charges	200,000,000
Retail Value of Cars and Trucks	4,100,000,000
Value of Motor Vehicles Sold for Cash	1,000,000,000
Value of Motor Vehicles Sold on Installment Plan	3,100,000,000
Amount of Cash-Down Payment	1,000,000,000
Amount of Deferred Payments on New Cars	2,100,000,000
Amount of Deferred Payments on Used Cars	900,000,000
Volume of New and Used Car Paper Financed in Year	3,000,000,000
Amount of Paper Outstanding at Given Time	1,500,000,000

A careful tabulation made by the National Association of Finance Companies shows the total volume of retail automobile paper in the last year and the maximum amount outstanding at a given time, which is an important thing to bear in mind.

Credit buying of motor vehicles is a form of saving analogous to insurance. It mortgages the future by compelling one to put away a certain amount each month for a value-yielding investment. The same money placed in the bank, if it were placed in the bank, would in turn be loaned for any number of purposes, possibly financing an automobile plant, possibly for some less necessary purpose, so that the relative social gain or loss is difficult to determine. By doing his own investing the purchaser gets the immediate value of his resources.

The money thus invested becomes available to society and to the banker. It goes to the automobile builder and the persons he employs, for the raw materials he purchases, to the persons the raw-material manufacturer employs, and to the banks that husband the employes' savings. In short, the money goes back into current industrial use.

The automobile is a creater of tangible wealth in myriad instances. The development of the petroleum industry of today could not have happened without the car, and this is only one of the more striking examples. For the farmer, the traveling salesman, the suburban home owner, and the high-class laborer, the use of the motor vehicle is an actual time and rent-saving instrument, and this makes it a paying investment.

It is a significant fact that building figures for 27 Northeastern States, collected by the F. W. Dodge Co., show that residential building has increased from $450,000,000 in 1915 to $3,000,000,000 in 1925, the period of motor-car development. The motor vehicle has redistributed the population, bringing about a large increase in the ownership of individual homes. It has taken the citizen away from the crowded flats of the city to the more ample living of the suburbs. The use of the motorcoach has been a large factor in the elimination of the little red school-house, which, while a picturesque element in our educational system, is far from the standard set by the new consolidated schools, with their elaborate equipment for physical and mental training of the child and better grade of teachers.

We are but at the beginning of the development of an adequate system of highways despite all of the progress that has been made in the last 10 years. More roads are needed for local, State, national, and even international traffic, and the mere fact that the public of this Country is today spending between $8,000,000,000 and $9,000,000,000 annually in the acquisition of cars and for their upkeep is evidence that it will not only support but demands a reasonable road improvement. The influence of highway transportation is a dynamic force for the betterment of living conditions, not alone in our own Country but throughout the world.—Bolivar E. Kemp.

Automobiles of Today and Tomorrow

By HERBERT CHASE[1] CLEVELAND SECTION PAPER

ABSTRACT

TO show that much room for improvement in present cars still exists and to stimulate thought and discussion along this line, the author discusses recent improvements in external finish, component parts and engine accessories and indicates lines along which further developments are desirable and to be expected. The subject is treated in the reverse order to that in which the engineer usually thinks of a car, as it is the outside of the car that has changed most radically in the last few years. Nitrocellulose lacquers produce a finish that preserves a good appearance for 3 or more years and have reduced to a fraction the time required for finishing, but the great depth of luster possessed by the more expensive cars is produced by applying high-grade finishing varnishes over lacquer undercoats. When the top coat becomes scratched and dull, it can be rubbed down and a new coat of varnish applied.

Hope is expressed that ways will be found to build lighter and more flexible bodies which will be accepted by the buying public. Such bodies will permit lighter chassis construction, particularly if stiffness of frames is not necessary, and a reduction in the quantity of material used should decrease the cost. The same results can be accomplished if large quantities of lightweight metal of nearly equal strength with steel should become available at moderate cost. All-metal bodies, if formed of aluminum-alloy sheets, could be very light and might also be fairly flexible.

Both chassis and bodies are being built lower to meet public preference, and the deck, rear and quarter panels of closed bodies and the fenders and splash aprons are beginning to be finished more durably and in colors instead of black. Drivers' seats are made adjustable in some makes of car, and experiments with seats having back-rests that move up and down with the passenger have given satisfaction. Better ventilation and heating of closed cars are receiving attention; windshields should be more easily adjustable and rear windows should have regulators.

The trend toward high speed in engines has an adverse effect on durability. The lower-speed engine wears longer and can be made light and still give high torque at low speed. The author predicts that some form of constant-compression engine, perhaps operating on the two-stroke cycle, will command attention. Air-cleaners and oil-filters are likely to become general but may be rendered unnecessary by design changes and the adoption of evaporative, or steam, cooling, whose many advantages are enumerated.

Radical chassis changes seem unlikely unless body construction is altered materially. Some torque-multiplying device that will displace the gearset may eventually be produced. Clutches are easier to operate, give more gradual engagement and have less spinning-weight than formerly. A promising self-locking differential has been given some extensive tests and is worthy of further investigation. Various types of four-wheel and power-operated brake are receiving intensive study. Much improvement has been made in spring-suspension, and the possibilities of pneumatic suspension have not been exhausted. Systems of chassis lubrication from the driver's seat have been adopted by a number of car builders and are likely to become general on the higher-priced chassis. Steering mechanisms have undergone numerous refinements, largely as the result of using balloon tires, and disc wheels and drop-center rims are likely to be used extensively.

USUAL practice is for the engineer to start inside the car and look outward, so to speak. I shall begin outside and look in, for it is the outside of the car that has changed most radically in the last few years. In fact, a revolution has been worked in car finishes, while no such radical change has come about in any other feature of the car. If anybody thinks that finishes and finishing are not engineering subjects, let me say that they should be and are becoming so rapidly.

Engineers and chemists today are concentrating on the problems of finish as they never did before and are making rapid progress toward sound engineering solutions, as is made evident by the fact that most cars today have a finish that is good for 3 or more years of service, or abuse, as it would be called by a carriage builder, while 3 years ago any finish that looked well for a full year on a car that was exposed to the weather daily and to the usual careless washing was a rare exception.

Nitrocellulose lacquers have worked this revolution and are used today as finishing coats for practically all cars save those at the extreme ends of the price scale. Many of the better cars now have undercoats of nitrocellulose-base also, for at least one company has learned to make such coats having adhesive qualities equal to the best oxidizing oil type and far greater durability, while the drying time is reduced to a small fraction of that needed for the oil type, even when forced drying is employed.

The elimination of drying ovens, which are necessary in rapid production work if primer and surfacers of oxidizing oil type are used under top coats of lacquer, not only saves much space and overhead expense on such equipment, but also results in a saving of fuel which often is as great as the cost of the materials being force-dried. Moreover, with a system in which lacquer-base undercoats are used, all of these coats are applied in 1 day or less and the body can remain on the production line instead of being shunted into ovens between coats. Naturally, this results in material savings in production cost.

VARNISH OVER LACQUER GIVES DEEP LUSTER

At the National Automobile Show in New York City last January many of the finest bodies had varnish finishes, while at the New York Automobile Salon, which is confined to the higher-priced products, less than 10 per cent of the cars shown had lacquer top-coats. This indicates that buyers of the more expensive automobiles still want bodies with a depth of luster that is not attained commercially as yet with lacquer, in spite of the fact that even the best varnish is admittedly much less durable and far more easily scratched than lacquer. High-grade lacquers that are suitable for automobile use do not dry with much gloss. If an excessive proportion of gum be added to give gloss as the lacquer is sprayed, durability is sacrificed. To secure both gloss and durability, it is common practice to resort to polishing the final coat of lacquer. This improves appearance but

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cannot give depth of luster, for the shine is all on the surface.

True depth of luster can be produced only by applying a transparent film of considerable thickness, hence some companies are using two coats of high-grade finishing varnish applied on lacquer undercoats of Nitro-Valspar. I give the trade name in this case because, so far as I have been able to learn, this is the only lacquer that "takes" and holds varnish successfully. It is the lacquer referred to by President Lítle when, speaking before the Metropolitan Section during the New York City Show, he said that Lincoln cars now have lacquer-type undercoats with a "high-gloss finish." Those who examined the Lincoln cars at the show and the Salon could hardly fail to note their exceptional brilliance and depth of luster. A high-grade heavy-bodied finishing varnish will give this luster. When such varnish is used over lacquer-type undercoats designed to take it, the combination is asserted to be the most durable of any with a varnish finish. Moreover, when, with this combination, the varnish becomes scratched or checks, as even the finest varnishes do in time, it can be rubbed down and revarnished without renewing the undercoats, for they do not fail with the top coats as in an all-varnish system.

One question naturally arises: Why not use a clear lacquer to give depth of luster over lacquer enamels such as now form the final coats of all-lacquer finishes? There are two reasons: First, lacquer coats are exceedingly thin, only a small fraction of the thickness of varnish coats, hence many coats are required to give the physical depth necessary to match varnish luster. This would make the cost excessive. Second, transparent films of lacquer that may give good service if used indoors are attacked when exposed to the ultra-violet rays of sunlight and disintegrate comparatively fast, whereas, when mixed with pigment, as in a lacquer enamel, the light is excluded and an extremely durable product results, providing, of course, the remaining ingredients are such as to give sufficient flexibility and the other physical qualities required.

Progress in the art of making lacquer finishes is now so rapid, however, that it is rash to predict what may come about in the near future. Small wonder, when lacquer has worked a complete revolution in automobile finishing in so short a time as 2 years. On the other hand, lacquer has a long way to go before it replaces varnish entirely, if ever, even in automobile finishing. This is true especially in the smaller refinishing shops where brushed-on varnish is likely to be used extensively for many years to come and where a varnish enamel makes an inexpensive high-luster finish that often will last as long as the car to which it is applied will remain in service.

Light Flexible Bodies Desirable

If the industry should improve the durability of the remainder of the vehicle as much as it has that of the finish, the consumer will have less reason for buying new cars every 2, 3 or 4 years, than he has had in the past. While lower prices have not always been accompanied by the better quality that we usually are told goes with them, evidences of improved design and construction are not lacking and it is hard to refute the claim that today a dollar buys more car value than ever before, especially when the depreciation of the dollar is taken into consideration. Certainly car appearance has been improved many fold, while the lowered cost of closed bodies testifies to the fact that body builders have rapidly adopted the same production methods that long have characterized chassis production. As evidence of this, we are told that the average closed body that is built today costs about one-third as much as a very similar structure cost a few years ago. Here, as with chassis production, the chances of competitive advantage due to improved quantity-production methods appear to be less than those that some radical improvement in design might bring.

Is it too much to hope that ways will be found to build lighter and more flexible bodies so that lighter chassis can be used and less rigid frames will be required? Efforts in this direction have been made abroad, apparently with fair results, but little headway has been attained with flexible bodies here, and those who have studied them are inclined to the view that our buying public will not accept the type of coachwork which such bodies involve. Whether or not this is correct, it cannot be denied that the heavier the body the heavier must be the chassis to carry it, and if the body is designed so as to demand a stiff frame it will prove difficult to effect the desired decrease in weight.

Cheap Light Metal Would Reduce Weight

It is well to remember that most of the materials that make up a car are bought on a weight basis and that the material item represents from 75 to 90 per cent of the first cost of the vehicle. Hence, do what it will, the production department, aside from preventing waste, cannot hope to effect much further reduction in manufacturing cost. Even though the labor item be reduced 50 per cent, the effect on car cost is likely to be less than 10 per cent. If, on the other hand, material cost can be halved, car cost may decline about 40 per cent. This serves to emphasize the need for weight reduction; but body weight must be reduced before much saving in chassis weight can be effected unless, of course, materials of lighter weight but nearly equal strength become available at moderate cost. We have hardly started the developments toward weight reduction which might come about if our natural power resources were turned toward the production of aluminum on a basis such as to make the price somewhere nearly comparable with that of steel.

All-metal bodies have certain real advantages beside the better vision that smaller pillars make possible, and, if formed of aluminum-alloy sheets, can be made very light. It is not unlikely, also, that they can be made flexible if this is desired as a means for permitting the use of lighter and less rigid chassis frames. Nearly all bodies are made heavier than would be necessary if they were relieved of chassis stresses. This might be accomplished, or these stresses greatly lessened, by the use of some form of flexible mounting that might also be made so as to lessen the transmittal of vibration from chassis to body. At least one Velie body has a support of this character under the windshield pillar, while a form of pneumatic cushion has been used on some British bodies.

Considerable saving in weight and greater safety will be possible when a light, flexible, non-shatterable substitute for glass which possesses an equal transparency, durability and resistance to scratching is available. Research in this direction is going forward in some laboratories and should be encouraged elsewhere.

Trend to Lower Cars and Improved Seats

Lower chassis and bodies are becoming increasingly popular and have resulted in smarter appearing and safer cars. Some engineers contend, however, that a car which brings the passenger closer to the road gives him

because of proximity to the ground, a sense of traveling at higher speed for a given actual rate of travel, and hence tends to increased fatigue on long trips. However this may be, the public seems to want lower cars and is likely to get them.

Experiments with seats having back-rests that are attached to the cushion base and move up and down with the passengers have given excellent satisfaction in the Chrysler roadsters and are worthy of trial elsewhere. A few companies now offer cars with adjustable drivers' seats and many cars have adjustable pedals, but the need still exists for improvement in comfort for the driver, especially when he or she is of abnormal proportions. Anything that tends to reduce fatigue in driving is a step in the direction of greater safety, and nothing that tends to make driving safer should be overlooked.

Means for better ventilation and heating of closed bodies are needed and are receiving study. The windshield should be made as easy to adjust as side windows, and regulators should be applied also to rear windows to assist in ventilation in summer. Steam radiators are one promising solution of the heating problem.

Now that cars are easier to keep clean on the outside, which is one desirable characteristic of lacquer finishes that I did not mention, why not also make them easier to keep clean inside? Leather, both real and artificial, answers this purpose and now is being made with a "feel" similar to that of fabric. Room for further improvement remains, however, and this should prove a fruitful field for research work in the leather, textile and related industries.

Durable Colored Upper-Structure Finishes Coming

The need also exists for more durable coated materials for use on the deck, rear and quarter panels of closed cars. Probably the rapid improvements that are being made in automobile lacquers will benefit the maker of coated fabrics and enable him to furnish the body builder with a more durable as well as a more attractive fabric leather.

Another benefit that lacquer has worked in the automobile field is seen in the variety of durable colors now used. Black, once so popular because cheaper and more durable than many colors, has lost most of these advantages and was seen on less than 10 per cent of the cars exhibited at the New York City Show. Black is still used extensively on superstructures, fenders and splash aprons but even there is giving way to colored lacquers in some cases, with great opportunity for originality in pleasing color-effects. Some think that even the deck covering, now almost universally black, will be furnished in a variety of colors on stock models before many years.

It is recognized rather generally today that body design and finish have a most important effect upon sales, hence they are being given much more study by engineers. There is no need to conclude, however, that the public has lost interest in mechanical features of the car or that these features are any less important than heretofore. Popular attention to four-wheel brakes, eight-in-line engines and better chassis lubrication has not been lacking, while other developments that improve performance, safety, comfort, and convenience are not likely to be overlooked, especially when they produce an effect that is readily perceived by an average user.

Engine Type May Not Be Final

Some engineers feel that the tendency of the last few years to build higher-speed engines has not been without its adverse effects, especially in respect to durability. It is certain, in any case, that the possibilities of lower-speed engines with higher torque have not been exhausted. Other things being equal, the lower-speed engine is likely to wear longer, have less vibration and lower friction-losses. In some cases it weighs more but engines can be made light in weight and still give high torque at low speed, which is the requirement for good accelerating ability.

An unfortunate disposition is found in some quarters to take the view that the present conventional throttling four-stroke engine is the highest engine development and never will be displaced. Even to mention a two-stroke cycle is likely to bring a knowing smile indicating that it is outside the pale of respectability, dead and buried years ago, never to be mentioned again in polite engineering circles. Nevertheless, I venture again to predict that some form of so-called "constant-compression" engine will command attention that it is as likely to operate on a two-stroke as on a four-stroke cycle. Whether this comes true or not, I am confident that some way will be found to improve materially upon the very poor economy of present engines under the low-load conditions that prevail during fully 80 per cent of the time of passenger-car operation.

Design Changes May Reduce Engine Wear

Much has been done in the last 2 or 3 years with the intent to improve the lubrication and decrease wear in modern engines. This has resulted in the application of filters and exhaust-heated stills for oil purification and of air-cleaners, all of which have their merits, but at the expense of considerable complication. It seems to me that air-cleaners and oil-filters, if they do their work effectively, are likely to stay with us in some simple form, but devices for removing fuel and water from lubricating oil may well be rendered unnecessary by design changes that will prevent oil diluent and water from reaching the crankcase, or, if they do reach there, that will cause them to evaporate quickly. I have in mind evaporative, or so-called "steam," cooling, and am frank to say that any automobile engineering department that is not giving such systems careful study is overlooking one of the most promising major developments of recent automotive history.

Unfortunately, some engineers who should and would know better if they analyzed the real situation, seem to have jumped to the conclusion that, because ordinary water-cooled engines sometimes have given trouble when steam is formed too rapidly in the jacket, it is the height of absurdity to think of a system in which steam is deliberately allowed to form. Such a conclusion takes no account of altered conditions, nor of the fact that many thousands of engines with evaporative-cooling are operating successfully at or near full load day-in and day-out and have been doing so for years, some with and some without radiator condensers. Engines with open hopper-jackets in which the water boils away are used daily the world over. Let the steam generated rise into a radiator condenser placed in a draft of air and permit the condensate to run back into the jacket, as has been done by at least one engine builder for many years, and you have a complete self-contained evaporative-cooling system. That is practically all evaporative-cooling is, yet to apply it to an automobile has been considered revolutionary, almost unthinkable.

Advantages of Evaporative-Cooling

No development that offers the advantages of evaporative-cooling, simplicity and lower cost included, can be

ignored very long, and some car builders are known to be considering the early adoption of this system. At least one maker of such systems now is offering them for replacement purposes. It will suffice here to enumerate some of the major advantages of evaporative-cooling:

(1) Smaller, lighter, cheaper, and practically non-freezable radiator

(2) Rapid warming of engine and constant temperature of jacket thereafter, regardless of load

(3) Relatively slow cooling when engine is stopped

(4) Elimination of thermostats and shutters and of supplementary tanks for catching solution boiled out of radiator

(5) Substantial elimination of contamination of crankcase oil by fuel and water

(6) Heating of bodies by steam radiators

(7) Virtual elimination of over-heating such as is common with conventional water systems during long hard pulling

(8) Approximate elimination of loss of cooling solution, even with leaky radiator-core

(9) Convenient small-diameter piping for entire system of cooling and heating, except jacket outlet-pipe

(10) Increase in fuel economy

It is worthy of note that most of these advantages are of even more importance on trucks and motorcoaches than on passenger cars, and, so far as I have been able to discover, are not offset by any disadvantages that are not of altogether secondary importance.

Recent years have seen numerous detail refinements in engines and their supplementary equipment, and more are certain to be made from time to time, but I believe I have covered the fundamental engine changes that, in our present knowledge of the art, seem probable within a decade.

Radical Chassis Changes Seem Unlikely

Chassis changes seem less likely to be of such radical character, unless body design is altered materially to make a more-flexible chassis construction feasible. Present tendencies are all toward a more-rigid frame structure and it is possible that channel sections may be abandoned in favor of thin-walled tubes welded together as a means of increasing torsional strength and preventing distortion; but this is a structural rather than a fundamental change.

Somebody may yet devise a torque-multiplying device capable of displacing the present gearset, but the conventional type is an inexpensive, compact, simple, and serviceable device that performs its function with the minimum of attention, and this is a combination that is hard to beat, even though it sometimes is called unmechanical, because of its intermittent torque and the skill required in its operation. Anything that is likely to displace it probably will need to have all of the good qualities of the gearset plus continuous and infinitely variable torque characteristics and ease of control by inexpert operators. This is a large order but not an impossible one. One gyroscopic device that seemed, on paper, to fill these requirements was found, upon test, to do so but fell short in that it gave the maximum torque multiplication of only 2 to 1. Students of the gyroscope, however, are giving the problem careful study and may yet find a simple solution. Or it may come along other lines. The mere addition of devices to the conventional gearset, however, with a view to making its action fully or semi-automatic, or substantially fool-proof, has not been and seems unlikely to be altogether satisfactory.

Clutches have been undergoing refinements in design, many of which were urged in a paper I presented before the Society about 5 years ago. It is now common to find that clutches are easier to operate, longer lived and have less spinning-weight than formerly, while more gradual engagement is the rule. I have heard of nothing fundamentally different in clutch design that is likely to be seen in production, but a transmission that needs no clutch is not beyond the realm of possibility.

Rear-axle design has changed but little in recent years except in details. Most large-production designs use pressed-steel housings. Straddle mounting of the pinion-gear is growing in popularity but, with one notable exception, no important change in the gearing design has come to my notice recently. Stutz has adopted an underslung worm, partly as a means for lowering the chassis and body, but otherwise the spiral bevel-gear is practically universal and satisfactory.

A promising form of self-locking differential, designed by C. Andrede, has been given some extensive tests and will bear further investigation. It seems to be of simple and rugged design and to perform the necessary functions of a differential without having the usual disadvantages. Neither drive wheel can spin independently of the other even though mired or lifted entirely free of the ground.

Power Brakes Receiving Much Attention

Four-wheel brakes apparently have come to remain, yet Dodge, Reo, Franklin, and Lincoln still are doing without them successfully in the face of strenuous competition, a fact which indicates that they are not essential, although they have certain well-recognized advantages. Both the hydraulic and mechanical types are "making good" and both types are being made with servo, or self-actuating, features. Timken's hydrostatic brake that has been adopted by Stutz, constitutes one of the few recent departures in brake design and certainly has simplicity and a uniformly applied pressure, as well as a very long arc of contact, to commend it. Like other departures, however, only practical service tests in the hands of ordinary users can tell the whole story.

Much interest is being evinced in the revival of the vacuum-operated brake, once widely discussed and later almost forgotten. Although this type of braking mechanism adds some complication, it makes the brakes very easy to operate and does not interfere with mechanical operation in case of any failure of the vacuum or of the parts involved in applying the pressure difference to the brake linkage. Moreover, it does not require a separate compressor, storage tank or such extensive piping as is needed in pneumatic systems.

Improved Suspension and Central Chassis Lubrication

Great improvement in spring-suspension has come in recent years and is due largely to the use of extra-long springs, usually of the semi-elliptic type and in general designed to be approximately flat under normal load. Such springs, plus balloon tires, have given far better riding-qualities, but further improvements are possible. While types of design in which both front and rear axles are displaced by special types of transverse spring generally are considered too radical for serious consideration, some designs along this line have given promise, both in weight-reduction and in improved riding-qualities. They are deserving of further study.

Not all the possibilities of pneumatic suspensions have been exhausted, and the introduction of non-metallic shackles in new designs seems likely, since such shackles have established their worth. Their cushioning action tends to prevent shock and vibration from reaching the body and is a good attribute, while the fact that they need no lubrication is a pronounced advantage. Similar types of construction for attaching torque arms and engine supports to the frame of the chassis already are employed with success and appear likely to come into wider use.

An ideal long held by engineers who are wide-awake to the owner-driver's viewpoint is that of making a car which will run with next to no attention from the driver beyond an occasional filling with gasoline, oil and water. A long step in this direction is the application of a centralized chassis-lubricating system that preferably is kept filled by the engine oil-pump. Several systems of this general class are in use today. Only one of these, so far as I am aware, is self-filling, but they are a vast improvement over systems that require oil or grease to be applied at a dozen or more bearings on the chassis Such intermittent lubrication as is given to most present-day chassis, even when done as directed, is far from ideal and is such a dirty job that it is the rule rather than the exception to neglect it. Few improvements seem to me so important as a simple well-designed central chassis-oiling system, and I look for the general adoption of such a system in the near future, at least on all higher-priced chassis.

Trend in Steering, Wheels and Rims

Front axles and steering systems have been undergoing numerous refinements in design in the last 2 years, chiefly as a result of problems introduced by front-wheel brakes and balloon tires, especially that little-understood phenomenon called shimmying. The addition of special damping devices to avoid this trouble has not been necessary thus far in most cases and it is hoped that it will not be required in the future, as the addition of any supplementary equipment that is not essential, or at least a great convenience, is far from being desirable.

Balloon tires, although they did not involve much change in basic design as compared with high-pressure cord tires, constitute one of the major automobile improvements of recent years. They are used as standard equipment on nearly all cars except a few of the largest and heaviest ones, and will be permanent. They certainly have added to the comfort and probably also to the safety of motoring. Although they have made steering harder, that disadvantage has been overcome largely by using steering-gears with a greater reduction.

Disc wheels have gained much in popularity and are likely to continue to do so, if for no other reason than that the supply of suitable wood for spoked wheels is failing.

Drop-center rims have certain advantages that make a strong appeal to users who change tires themselves. Their general adoption has been delayed for various reasons, but if ever the public learns how easy they make tire-changing, they are likely to come with as much of a rush as balloon tires did.

In a paper of such a general character as this one, to go into much detail on any one subject is impossible. My purpose has been to show that much room for improvement in present-day cars still remains and to stimulate thought and discussion along this line. Few things are so bad for industry or individuals as a complacent belief that what we have today is good enough or not capable of improvement.

THE DISCUSSION

ERNEST WOOLER[2]:—Mr. Chase gave a list of the advantages of steam-cooling. Would not a list of the disadvantages include that of less power? The steam cooling-system is not non-freezable, is it? What happens if alcohol or glycerine is used in it? Even if the radiator cannot freeze, cannot the small-diameter pipes and connections freeze quickly?

I am sorry that Mr. Chase did not say more about engine design and improvements, especially about such parts as crankshafts and the number of main bearings, which seems to me to be one of the most varied and debatable points. What about double flywheels and other vibration dampeners?

What is Mr. Chase's opinion of the future of the supercharger on passenger cars?

To my mind the transmission, or gearset, is the one unit of an automobile that has been most sadly neglected. With the many compulsory stops that necessitate gear-shifting so much oftener than formerly, some improvements should be made. Is Mr. Chase aware of any developments in transmissions?

He stated that the spiral-bevel gear is satisfactory. I think our biggest production problem is to obtain quiet gears although considerable improvement has been made in the way of detail changes. Even tooth-form and the spiral-bevel gear itself are receiving intensive study at present, perhaps to offset the worm-drive development.

Mr. Chase omitted mention of four cars in large production that do not have front-wheel brakes. They are the Ford, Chevrolet, Hudson, and Essex.

Steam-Cooling May Require Heavier Oil

HERBERT CHASE:—I stated that the radiator core of the steam cooling-system is practically non-freezable. The core remains dry because the water is in the lower tank. The water in the jacket and pipes will freeze just as in an ordinary cooling-system if the temperature drops below the freezing-point of the solution used. It is possible to use alcohol, and I have no doubt that it would be possible to use glycerine. When alcohol is used there is a distinct advantage in that when vaporized it is condensed and retained within the system.

The only disadvantage of the steam cooling-system that I know of is one that has been brought to my attention since writing the paper, that is, the possible difficulty involved in using heavier oil, if the higher engine-temperature demands its use. Heavier oil increases the difficulty of starting during cold weather, but that difficulty can be overcome by mixing with the oil a certain quantity of kerosene, as is done in some cases today when starting becomes too difficult.

The system may be run at a slightly higher temperature than the water-cooled system, if desired, but, by using alcohol, and thus lowering the boiling-point, any desired temperature can be realized. If lighter oil be used to facilitate starting, it may be found to have insufficient body at the higher operating-temperatures. I have not been able to "see" the advantage claimed for the supercharger. Its purpose is to increase power without increasing piston displacement. I maintain that it is much easier and wiser to get the amount of power required by building the engine slightly larger and keeping it simple. Certainly that is much to be preferred to the added complication that the supercharger involves.

[2] M.S.A.E.—Chief engineer, Timken Roller Bearing Co., Canton, Ohio.

The points that Mr. Wooler makes with regard to improved crankshaft-design and the use of double flywheels are well taken. I avoided any extensive discussion of engine design because I have been somewhat out of touch with that recently. I believe that the larger number of bearings, which seems to be popular today, is desirable.

Vibration dampers have been used successfully but I think that some engineers, when adding such refinement, failed in some cases to remedy inequalities in distribution which leave the engine as rough as before because of resultant inequalities in torque.

Gearsets and Spiral Gears Function Well

As to the present gearset, I do not contend for a moment that it is ideal. I am inclined to agree with Mr. Wooler that it has received less attention than it should have had; however, its simplicity is hard to beat. I believe that some mechanism will be found ultimately to displace the gearset, one that will give continuous instead of intermittent torque, but I do not know of any very promising development in that direction unless it be the gasoline-electric transmission, which is almost unthinkable for the passenger car. The fact that the present conventional gearset has survived so long and is used in practically all cars except the Ford proves that it is a fairly satisfactory device. It is one of the parts of the car that gives very little trouble in service.

The spiral gear is also a very successful device if success can be measured by almost universal use. I am aware that the production of the gear and refinements in tooth profile and the like have involved difficulties. They are receiving study that will result in improvement, but the gear itself, which originally was scoffed at by many engineers including particularly a number of Continental and English engineers, has been adopted generally in this Country and in Europe.

Types of Steam-Cooling Radiators

George V. Albright[3]:—Can the present type of cooler be changed?

Mr. Chase:—The Harrison Radiator Co. is offering a steam-cooling replacement system claimed to be suitable for any car fitted with a pump.

Mr. Albright:—Is the same radiator used?

Mr. Chase:—The basic construction of the radiator is the same except that the inlet is at the side and the passages in the radiator are horizontal. In the Rushmore system the passages in the radiator are vertical and the steam entering at the bottom rises into the core.

It is very necessary to provide some type of construction whereby the air is excluded from the core. If the core is filled with air, of course, the steam cannot enter. It is possible to design the core with very simple changes so that the steam will come in at the bottom and force the air out at the top. Then the steam will be condensed readily. One car that I drove, with the steam cooling-system installed, was equipped with a gage that showed the pressure in the radiator, and this pressure was below atmospheric most of the time. Air is forced out at the start and when the steam is condensed the system often works below atmospheric pressure.

Mr. Albright:—Has steam-cooling ever been tried on aviation engines?

Mr. Chase:—It is being tried not only in this Country but abroad. One prominent company here is experimenting with it.

Needed Improvement in Charging Generators

Park D. Manbeck[4]:—Are any developments being made to improve the electrical system, for example, the generator? There are very good devices for regulating the current at different speeds but they operate directly opposite to the way we want them to do, which is to charge the battery when the voltage is low. They do not charge the battery when it is low; but when the voltage is up, the charging rate is high.

Mr. Chase:—I am not sufficiently familiar with the detail of electrical-unit design to answer that question.

Ferdinand Jehle[5]:—I think the voltage regulator takes care of that.

Mr. Manbeck:—That was used sometime ago but is not in general use today. It operates all right while in good condition but sometimes it gets out of order. The third-brush generator is the system most used today, but it gives us just the opposite from what we are trying to get.

Mr. Jehle:—All of the motorcoaches today are using voltage-regulating systems. Two companies are making these systems and they seem to be working well. Formerly almost all of the electrical companies made voltage-regulating systems, but the car builders will not pay for them.

How High Temperature Affects Cooling Systems

Samuel K. Wellman[6]:—Water-cooled engines often perform poorly under conditions of boiling, probably due to overheating at certain spots in the jacket where steam-pockets are formed. Assuming heavy-load conditions, and if no change is made in the water-jacket construction, why is this same trouble not encountered with the steam-cooled engine?

Mr. Chase:—Water cooling-systems have given trouble when steam is generated and not quickly expelled from the jacket. In the usual water-cooled engine having a pump, the whole system is filled with water, including the outlet pipes and jacket. When steam begins to form because water does not carry the heat away with sufficient rapidity, the steam expands and tends to find an exit through the overflow pipe. In so doing the steam traveling at high velocity due to the considerable pressure-difference, entrains considerable water. If the pressure continues to rise, the centrifugal pump does not deliver much water; in fact, the steam formed in the jacket may force the water back through the pump into the radiator at the same time that it is overflowing the radiator from the top of the cylinder-block. When water is forced out of the jacket, of course overheating occurs. This can occur even in normally operating systems, due to the fact that the jacket is not properly vented.

In the Rushmore steam-system the jacket space is filled with water but the outlet pipe has little, if any, water in it. A small positive pump which feeds water to the jacket only in sufficient quantity, or slightly in excess of the quantity, necessary to replace that evaporated is used. Only a small trickle of water goes through in the normal size of water pipe and the rest of the pipe is free for the steam to escape, hence there is no cause for the formation of steam pockets as in the ordinary water cooling-system. Conditions in the steam cooling-system are similar to those in the ordinary thermosiphon system. The thermosiphon type of engine is partly steam-cooled under high-load conditions. In

[3] A.S.A.E.—Vice-president, Akron Oldsmobile Co., Akron, Ohio.

[4] A.S.A.E.—Electrical engineer, works laboratory, National Carbon Co., Cleveland.

[5] M.S.A.E.—Research engineer, White Motor Co., Cleveland.

[6] M.S.A.E.—President, S. K. Wellman Co., Cleveland.

the steam system water is constantly evaporated after it reaches the temperature of boiling.

MR. ALBRIGHT:—What is the percentage of gain or loss over the water cooling-system with regard to the quantity of water carried?

MR. CHASE:—I am unable to give the exact figures but the chief gains are in the smaller piping, the fact that the core is not filled with water and also that a smaller core can be used because the difference in temperature between the cooling medium, which in this case is steam, and the air is greater. With the water system, the water is held at a temperature of 180 or 190 deg. fahr., whereas the steam is 212 deg. or slightly higher.

FUEL ECONOMY MAY BECOME BIG PROBLEM

T. V. BUCKWALTER[7]:—Early in 1925 the unit price of rubber and gasoline was about the same, 20 cents per lb. for rubber and 20 cents per gal. for gasoline. Then the production of automobiles increased and probably a 20 or 25-per cent increase in cars used followed. The supply of gasoline was increased in proportion, but no material increase in the price of fuel was made. The price of rubber late in 1925 reached $1 per lb. It takes 4 or 5 years to bring a rubber plantation into production but this great increase in the price has spurred the rubber-producing countries to activity and in the short period of 1 year they have increased their supply. This has resulted in a marked decrease in the price.

The oil companies have kept pace in production with the automobile companies, but will that condition continue and what will happen if it does not? It seems to me that this possibility will cause the engineers to give their serious attention to the economies to be derived from the more-efficient use of our fuels. Suppose that gasoline and oil production continues about as at present and the production of automobiles goes up 25 per cent; it would not be surprising to see a 100-per cent increase in the cost of fuel, which would be a very serious matter. We would then be working on the problem of fuel and its more-efficient use rather than on such things as body finish and engine vibration.

PRESENT ENGINES THERMALLY INEFFICIENT

I am inclined to believe that we shall be compelled to devote much attention to the more-efficient use of these fuels. It has been brought out that 1 gal. of gasoline possesses enough energy to drive the average five-passenger car 600 miles, but we get only 15 or 20 miles from a gallon. Where does most of this energy go? The best information that can be obtained is that about 75 or 80 per cent is lost in the exhaust and the cooling medium, and probably 20 or 25 per cent is used to overcome windage and other friction. There is not much opportunity to reduce windage and very little to reduce mechanical friction, but there appears to be tremendous latitude for reducing the losses in the exhaust and the cooling medium.

Referring to Mr. Chase's paper, it would appear that the cooling medium offers one field in which a reduction of loss could be effected. I understand that 40 or 50 per cent of the gasoline energy is lost through the radiator. If we raise the temperature of the cooling medium to about 212 deg., as with steam-cooling, we increase the efficiency of the gasoline engine materially and reduce the losses in the cooling medium.

Steam-cooling has been well tried-out. Some engines, such as the Diesel type, have been equipped with steam cooling-systems for 20 years. The systems are automatic, with the water slightly above the cylinder-heads, and they use a pump no larger than a silver dollar to maintain the level. The cooling is effected by converting the water into steam, which is then utilized in the carburetion system and taken in through the intake manifold. It is a simple and efficient unit. I do not know that this is to be applied to the automobile but there is something to think about along this line, and along the other lines of which I spoke. If the economic trend is to continue, we shall have to give considerable thought to these subjects.

HIGHER TEMPERATURE DOES NOT INCREASE MILEAGE

MR. CHASE:—Many have claimed that increased mileage per unit of fuel burned results from the use of the steam cooling-system but I am inclined to doubt it. Such claims are explained as being due to better vaporization of the fuel and more nearly complete combustion. It is possible to decrease the jacket losses to some extent by steam-cooling but it does not follow necessarily that the engine economy will be increased thereby, for an increased loss through the exhaust may neutralize the gain. Engines run somewhat warmer, of course, with steam-cooling but I believe that all of the gain in economy is due to the fact that the fuel is more fully vaporized. Experiments made at the Bureau of Standards have shown that it is entirely possible to have liquid fuel in the cylinder and not ignite it during several explosions if the cylinder-wall remains cool.

I agree with those who believe we should do all we can to conserve our natural resources. We have heard this warning of fuel shortage sounded so many times that I am somewhat skeptical about its materializing for many years. Of course, we are always approaching nearer to the exhaustion of our fuel supplies, but it must be remembered that the petroleum industry has been making rapid strides in recent years. It now knows how to obtain more oil from a well that has been abandoned and has started such wells producing again by the use of new methods of drilling.

AMPLE FUEL RESERVES STILL AVAILABLE

A considerable proportion of the fuel now sold in this Country is so-called "straight-run" gasoline, which is simply the skimmed product; part of the remainder is made into kerosene and most of the rest is thrown into some form of fuel oil. It is possible, by a cracking process, to convert this residue into gasoline at only a slight increase in price. The technic of refining has undergone such development that today, I am told, it is theoretically possible to convert almost 100 per cent of the crude into gasoline, if that should become necessary.

Economists who have made a close study of the fuel situation are of the opinion that a time may come when we shall have a fuel stringency but not a fuel shortage. The tremendous growth in the demand for fuel has acted as a stimulant for new drilling and has created an increase in production. Increased drilling always has followed high crude-oil prices, but if our crude petroleum supply becomes exhausted, or the demand exceeds the supply, the reserve of the shale oil, which is enormous, is available. Shale oil is not an economic commercial product at present because it has to compete with crude oil that flows or is pumped out of the ground, but if the financial incentive is sufficient, oil can be produced from shale by a process that is comparable with mining. We may come to that some day.

[7] M.S.A.E.—Vice-president, Timken Roller Bearing Co., Canton, Ohio.

Constant-Pressure Engines More Efficient

Although we may have an ample fuel supply, I believe firmly that we should economize. It is possible that we shall produce cars that will increase the present mileage per gallon possibly as much as 50 per cent. Mr. Kettering has made the statement that cars will be doing 40 miles per gal. in the near future. One way of increasing the efficiency of the engine is to make it more economical under low-throttle conditions. The constant-compression type has an advantage at low throttle while the variable-compression type of engine has a thermal efficiency of 2 or 3 per cent or less under low-load conditions. At high loads it is almost as economical as the Diesel type.

Romuald Karasinski[8]:—Mr. Chase stated that it is not likely that the thermal efficiency of the engine would be increased by steam-cooling on account of the exhaust losses. It seems to me that the thermal efficiency and the increase in power for a given quantity of fuel consumed in an engine could be improved by more efficient utilization of the expansion stroke. If we could utilize all of the heat energy of the fuel on the power stroke and prevent the heat loss to the water-jacket, we could then afford to loose more heat to the exhaust. Since the heat loss on the expansion stroke is a function of the temperature difference between the explosive charge and the water-jacket temperature, it seems logical to conclude that the heat losses with the steam-cooled engine would be much smaller than with the conventionally-cooled engine and consequently the power and efficiency would be improved, as the mean temperature and pressure would be higher.

Mr. Chase:—In a test that I conducted many years ago, I secured some data which indicated that an increase in jacket temperature does not always result in higher economy. Theoretically it should do so, if you do not take into consideration that the volumetric efficiency decreases on account of the higher temperature of the incoming charge. In that test the engine did not operate at the temperature of boiling water. The test was between cold jacket-water and hot jacket-water operation. The results were reported to the Society at that time.

[8] M.S.A.E.—Assistant chief engineer, Maedler Syndicate, Cleveland.

Effect of Pockets in Cooling Systems

Mr. Jehle:—Why should it be easier to design the steam-cooled system free from pockets?

Mr. Chase:—Water chokes the outlet in the water-cooled system whereas in the steam-cooled system the steam has a free outlet; it is not necessary to accelerate the water.

A Member:—In some tests that I have made, considerable boiling-over occurred, although I left ample space for the steam. Have you ever had that trouble?

Mr. Chase:—That has not occurred in my limited experience. I do not mean to take the position that it is impossible to build a steam cooling-system that never will overheat, but if a free outlet is provided the danger of overheating is less than with the water-cooled systems in which the outlet steam is not free. The ordinary hopper engine used for farm and industrial work is a simple steam-cooled job. The Fairbanks, Morse Company has for years built an engine of that type for lighting sets. The engine has a hopper jacket and at the top of the jacket is a small radiator or condenser that cools the steam and returns the water to the engine. Those engines can be run on a full open throttle for long periods without any signs of overheating. Of course, the radiator is entirely above the jacket, so the possibility of trapping air is reduced and no special precaution against that is required.

FARMING

The recent farm crisis is by no means the first which the farmers of America have experienced. Indeed, we could go back into Colonial history as far as 1716 and from then on find intermittent periods of depression in which the farmer has always severely suffered. In all these periods we would find a peculiar parallelism in underlying causes, mainly, a too rapid expansion of agriculture or industry, with speculative values established in good times and the contracting of debts in periods of inflation, which were paid at some later and less prosperous date at great sacrifice. I recently have gone through a study of probably seven or eight periods of depression, and I find that this is the story of every one of them. In every case, the farmers demanded Governmental aid in the curing of economic ills, and in every case, as soon as prosperity again came, the demand for legislation and Governmental aid immediately stopped. History is filled with the epitaphs of political parties that sprang into being for the correction by Government of distressing conditions, but these movements died immediately with the re-swing of the economic pendulum.

Good cotton lands sold as high as $1,500 per acre in 1835. This puts into the shade our recent speculative land boom in Iowa. Small wonder that there was a crisis of 1837 and that the *Congressional Record* of the following days is filled with relief measures of various sorts which were introduced by the Senators and Congressmen.

The year 1897 ushered in the greatest era of agricultural prosperity that any farmers of any nation ever experienced—extending with but few breaks to the period of the world war. Agricultural capital, building its surplus solely from its own resources, doubled in the decade from 1900 to 1910.

The statement that money has never been made in farming is fallacious. Farming has been, over the spread of years, just as profitable as any other business and will continue to be, but probably not much more so; else, as my father used to say, everybody would go to the farm. The balance between your business and mine will be automatically maintained.

The future of American agriculture presents a hopeful outlook. Production seems to have been overtaken by consumptive demands at prices of reasonable profit. The improved land areas are stationary and will never greatly expand. Rural population is also stationary, numerically, while National population is rapidly growing. As our relative volume of agricultural exports diminishes, which it will do over a term of years, we become less affected by the possibility of declining markets abroad and benefited by the improved domestic consumption. Good years and bad years will always be experienced. Depressions will, in all probability, come again from time to time as they have in the past, because prosperity will bring speculation and inflation bring deflation—just as has occurred many times in the past. But over a period of years an upward trend of agricultural prosperity extending over many years is indicated.—From an address by J. R. Howard before National Association of Farm Equipment Manufacturers.

The Cost of Operation and Economic Life of Motor Trucks

By Eugene Power[1]

Los Angeles Group Paper *Illustrated with* Charts

ABSTRACT

IN order to flourish, business must operate at a profit. As the margin of profit is daily becoming smaller, costs must be analyzed so that economies can be effected. As a lack of uniformity exists in the methods of arriving at the cost of operation, a brief outline is given of the items that enter into the totals from which operating costs are calculated and also of what constitutes the economic life of a motor vehicle.

Selection of the correct type and size of vehicle is of paramount importance; and standardization of the various makes will result in better operation, more efficient inspection, and more economical repair and upkeep. Having then determined the cost of operation of a vehicle, a decision must be made as to the basis on which its economic life can be computed.

The items said to contribute to operating cost are drivers' wages; gasoline and lubrication expense; repairs; tires; sundries, including taxes; license fees and insurance; depreciation; and miscellaneous charges, such as garage rent and the various items of overhead expense. Each of these factors is discussed in detail.

The economic life of the vehicle is dependent on the type and size of the unit, and the three principal causes of replacement: (*a*) physical depreciation, (*b*) unsuitability for the services for which it was purchased and (*c*) obsolescence. These factors are also given detailed consideration.

Charts show graphically the results derived from the operation of a cheap type of automobile over a 5-year period; the logical time for trading-in an old car for a new one; the cost of operation of 2-ton trucks over a period of 7 years; the annual replacement-cost and the average annual maintenance-cost over the same period; and the average prices of the automobile and the cost of gasoline, oil and tires for the same period, to furnish a basis of comparison between the price of the commodity and the cost of operation.

The conclusion reached is that, although any truck built by a reputable company will have an economic life of at least 8 or 10 years, it is essential in each case to take into consideration the conditions under which the truck operates; consequently, a rule that will govern all cases is difficult to derive.

THIS is an age of keen competition. It is felt in every phase of business life, being reflected, perhaps, most prominently in the sale of the finished product to the consumer. Necessarily, a business to flourish must operate at a profit and, as the margin between the manufacturing or production cost and the final cost to the consumer is daily becoming smaller, it is of the utmost importance to business organizations that they shall be in a position to analyze costs, for by doing so economies can be effected.

The item of delivery expense alone has a very important bearing on the final cost of any commodity. In the case of companies or individuals delivering merchandise direct to the consumers, whether it be by horse-drawn, electric or motor-driven vehicles, a careful analysis should be made of whatever system is employed, so that accurate information can be acquired of the actual cost of delivery.

Of late the trend has been toward more accurate cost-accounting, particularly by those operating large fleets; a lack of uniformity, however, is noticeable in the methods of arriving at the cost of operation. It would, of course, be impossible to design a system that would meet all conditions of operation but, in the aggregate, certain features apply in all cases. In this paper, a brief outline will be given of the items that enter into the totals from which operating costs are calculated and, also, of what constitutes the economic life of a motor vehicle.

Correct Type and Size of Vehicle

From the viewpoint of economical operation, the selection of the correct type and size of vehicle is, of course, of paramount importance; furthermore, standardization, by which the variety of makes in service is held to the minimum, has a direct bearing on operating costs, inasmuch as large investment in stocks of parts for various makes is avoided. Standardization results in better operation, more efficient inspection and more economical repair and up-keep, owing to the fact that drivers, inspectors and mechanics become thoroughly familiar with the peculiarities, if the expression may be used, and the mechanical details of the units. Assuming that selection and standardization have been satisfactorily taken care of, the next problem is the determination of the cost of operation, and this is followed by the equally important one of arriving at a decision as to when the unit will become of no further value, in other words, when it should be traded in.

What constitutes the cost of operation and on what basis may the economic life of each unit be calculated? The consideration of cost will first be dealt with. Broadly speaking, all items of disbursement incidental to the operation or maintenance of a motor vehicle can be said to constitute its operating cost. These may be outlined as follows:

Drivers' Wages

The first consideration should be the careful selecting and training of drivers. When they are selected and employed as drivers only, this problem can be readily solved; in such cases, however, as that of the company which I represent, in which they are chosen for their ability as salesmen rather than for proficiency in handling motor equipment, the solution is more difficult. The item of drivers' wages, therefore, has an added significance and is one that calls for thought, as it is within the power of any driver to increase materially the expense incidental to the operation of any unit. Local conditions and the scale of wages control this item to a large extent, but economy in this item may result in considerable additional cost appearing under the repair item.

[1] M.S.A.E.—Superintendent of automotive equipment, Union Oil Co. of California, Los Angeles.

Gasoline and Lubricants

Gasoline and lubrication expenses are, of course, controlled largely by maintenance. In other words, when the tendency of any unit is toward too high consumption, corrective measures can be taken either by adjustments or by changes, to offset the high cost. The accepted practice of changing lubricating oil after it has been used for a certain number of miles may appear to be expensive but, under present-day conditions, it is necessary and economical, in that it prevents undue wear of the engine because of the dilution of the oil in the crankcase.

Repairs

All charges in connection with inspection, maintenance and actual repairwork are properly made to repairs. As to the best method of keeping this particular item of cost down to the minimum, opinions differ. One method that has been advocated is a general overhauling at stated periods. Another is the unit-repair system by which units, such as the engine, the transmission or the differential, are repaired after certain mileages. Yet another system advocates continual maintenance with periodical visits to the main shop for a general going over. I am in favor of that last mentioned, for I believe it has a very important bearing on the economic life of the unit. In cases in which drivers are expected to make minor repairs, the portion of their time so spent is properly chargeable to the item of repairs. When traveling mechanics make regular inspections and adjustments, the driver's efforts are practically confined to lubricating the unit. In such cases, a segregation of the time so spent is unnecessary. These cases, of course, should be carefully watched by the management so that the item of drivers' wages may not be charged with legitimate repair expenses.

A check-up on the idle hours of the truck will be an automatic way of determining whether any slip-up occurs in this connection because, if the truck is being operated full time, the driver cannot be employed in any other way than driving. All expense incurred for repairs as a result of accidents, although properly chargeable under this heading, should be segregated, if a true operating figure, or one to be used for comparative purposes, is desired. A segregation of the expenses due to accidents also gives valuable data as regards a driver's carelessness, faulty design of any particular part of the unit or unsuitability of the vehicle to the work in which it is engaged. All items of replacement are properly segregated under the heading "Repairs," and entries can be made, if desired, in such a manner as to allow the determining regularly of the frequency of replacement of any particular item.

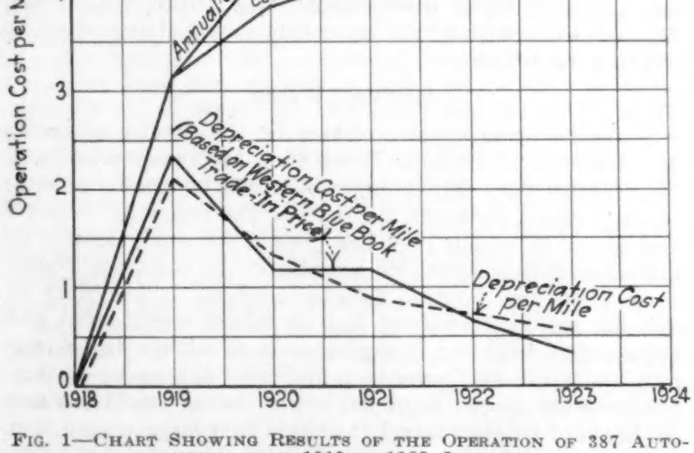

Fig. 1—Chart Showing Results of the Operation of 387 Automobiles from 1919 to 1923, Inclusive

Of This Number, 64 Cars Operated 1 Year; 112, 2 Years; 153, 3 Years; 23, 4 Years; and 35, 5 Years

Tires

Tire cost is another very important item that should receive careful study. In the case of new trucks equipped with solid tires, a possibility that the tire expense may be overlooked exists, because of the fact that replacement is not necessary, as a general rule, until the unit has traveled from 10,000 to 15,000 miles; hence, the cost per mile because of tire wear cannot be computed until after the tires have been in service for a considerable time. In cases of fleet operation the possibility of the elimination of tire cost is, of course, reduced to the minimum, owing to the fact that from a large number of units average operating costs are readily available. When few units are in service, however, this particular item should receive careful consideration.

Sundries

Taxes, State, county and city, also fees paid for licenses and insurance should be taken into consideration, for they constitute part of the operating expense. They can be classed under the heading "Sundries." In some cases it may happen that one unit will be assessed several times for a similar tax, as, for instance, the so-called peddlers' tax assessed by small municipalities against trucks making deliveries within their limits, when the trucks operate from centers outside these limits. It may be contended, and perhaps justly, that these charges cannot properly be considered as operating charges. They do, however, figure very prominently in the delivery cost of the products carried, hence, should be included in any calculation pertaining to it.

Depreciation

All operating costs must include depreciation. Consideration should be given to the type of equipment involved. Large trucks under ordinary operating conditions will not depreciate so rapidly as lighter and cheaper trucks. The depreciation of passenger cars, on the other hand, is considerably greater. It is necessary, therefore, to arrive at a fair basis for estimating depreciation. Opinions differ on this subject. Some advocate so-called straight-line depreciation, which, in the case of trucks, is taken as 20 per cent per annum, on the assumption that 5 years constitutes the life of the vehicles. Others adopt a rate of 10 per cent per annum, plus 10 per cent per 10,000 miles.

Another method is to take 25 per cent of the investment in a new unit as the assumed depreciation for the first year, then to reduce this to an hourly rate based on the assumption that the truck will operate 8 hr. per day, 26 days per month. The hourly depreciation-rate multiplied by the actual number of hours in operation during any period gives the depreciation for that period.

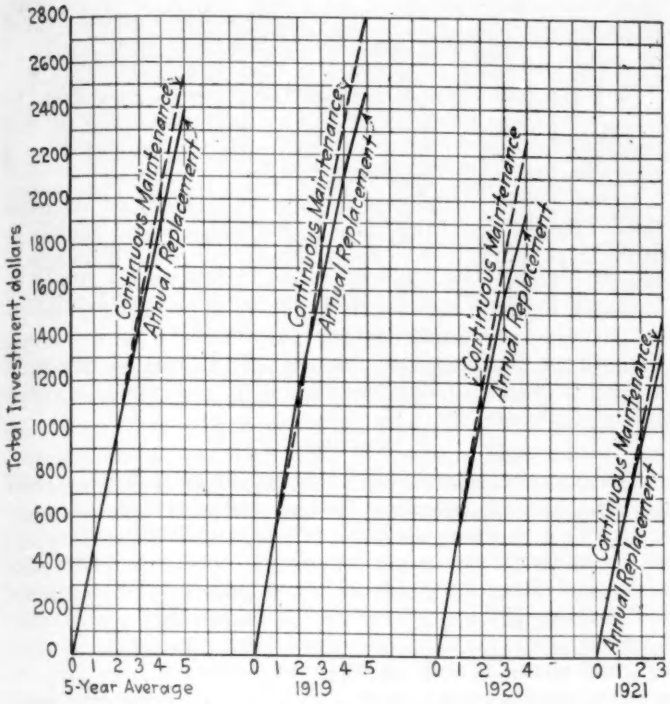

FIG. 2—COMPARISON OF CONTINUAL REPAIR COST WITH COST OF ANNUAL REPLACEMENT WITH A VIEW TO DETERMINING THE LOGICAL TIME FOR TRADING-IN THE CARS SHOWN IN FIG. 1

The Solid Lines Indicate the Expense Incidental to Annual Replacement; the Dotted Lines, the Expense Involved in Annual Repairs

At the end of the year, the total sum representing depreciation is deducted from the cost and 25 per cent of the remainder is taken as the basis for computing the depreciation for the following year. This method gives a gradually reducing scale of depreciation.

In my opinion, a gradual rate of depreciation to the minimum, depending on the cost and size of a unit, is a very fair method from a practical standpoint. Such, for instance, is the case of a 2-ton unit costing approximately $2,500 when depreciated to the minimum of, say, $450 or $500. Theoretical considerations from an accounting viewpoint, however, would indicate that such procedure would not be correct. Irrespective of the method of depreciation used, it is an item of operating expense that should be included in all systems and, although it may be considered a matter of bookkeeping or a theoretical problem, it can become a very practical one, if efficient inspection and maintenance are not maintained.

MISCELLANEOUS CHARGES

Other charges must also be considered, such as garage rent and all the various items of overhead expense, but these are charges that are influenced by the size of the fleet and its method of maintenance. No set rule, therefore, can be laid down, for it becomes an accounting feature of the individual or the company involved.

The foregoing is a brief outline of the items that must be taken into consideration when computing the cost of operation. As has been mentioned, a lack of uniformity exists in opinions on this matter. This lack of uniformity is, no doubt, due to the variety of conditions under which motor equipments operate.

The suggestion has often been made that a uniform system should be adopted along the lines of railroad practice. This, however, would be rather difficult of achievement; the best that can be done would be for those operating along somewhat similar lines and handling similar commodities to adopt a system that would uniformly meet their individual requirements. The day of the standard cost system of operation for all truck operators has not yet arrived.

ECONOMIC LIFE OF MOTOR VEHICLES

What constitutes the economic life of a motor vehicle? In other words, what is the economical time after which it should be replaced? This particular phase of operation has received considerable thought on the part of operators, and much has been said on the subject. It is difficult, therefore, to discuss it without covering ground that has already been very ably discussed. Due consideration must, of course, be given to the type and size of the unit. In an average truck, it is natural to expect the economic life to be much greater than that of a lighter or cheaper one. Factors enter into the consideration of passenger cars that do not exist in the case of trucks, changing styles and refinement of design being the principal ones in higher-priced cars, whereas, in lower-priced cars, it is the limit of their economic life, an example of which will be shown later on.

CAUSES OF REPLACEMENT

Dealing principally with the average truck, the situation may be summed up as follows. Three principal causes that may lead to the replacement of any unit are:

(1) The wearing out of the unit in service, or its physical depreciation
(2) The fact of the unit's becoming unsuited to the service for which it was purchased
(3) Obsolescence

The first item, physical depreciation, can be subdivided

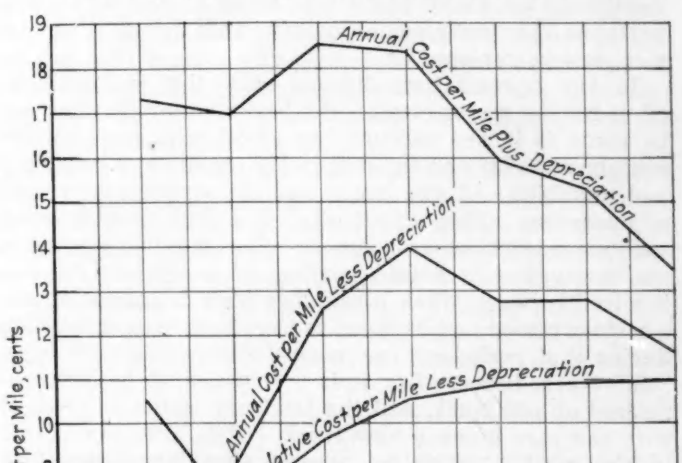

FIG. 3—AVERAGE COST OF OPERATION OF 2-TON TRUCKS FOR THE PERIOD, 1917 TO 1923, INCLUSIVE

These Figures Are Based on the Operation of 423 Trucks, Having a Total Mileage of 16,600,000 for the Period. Of the Total Number of Trucks, 47 Trucks Operated 1 Year; 61, 2 Years; 54, 3 Years; 58, 4 Years; 104, 5 Years; 67, 6 Years; and 32, 7 Years

farther. For instance, as a result of an accident or a fire, a unit may be totally destroyed, or injured to such an extent that the cost of rebuilding it would practically amount to that of investing in a new unit. Such cases, of course, are rare and are beyond the power of the operator to overcome.

Again, instances occur in which trucks are purchased for a specific purpose, the intention of the purchaser being to use them up on that work without any attempt at maintenance other than that necessary to keep them running. An instance of this would be a contract for hauling for a stipulated period. I have known of instances in which the successful bidder on the work purchased four trucks with the avowed intention of using them up on the job; and he did so. His quotation, however, amply took care of the depreciation of the units during the life of the contract.

Methods of Depreciation

This leaves physical depreciation, therefore, as the main consideration. Two distinct schools hold divergent views on this subject, one contending that after a stated period, depending on the initial investment and the type of the equipment, trucks should be traded-in for new ones; the other contending that with proper care, provided the model does not become obsolete, the life of a truck can be prolonged to 10 or 12 years or longer. My own thoughts on the subject are that the latter contention is correct, if careful and regular inspection is insisted upon and each unit is maintained continuously. There is no reason why a truck should ever get into a condition that would justify its being traded-in, because parts, as they wear out or become unfit for further service, can be replaced.

In any organization charged with the responsibility of operating motor trucks, the best investment that can be made is in the encouraging of all who work on the equipment to take an interest in the appearance, efficiency and reliability of the units and, of course, their cost of operation. This, admittedly, is a difficult task when such considerations as bonus or other tangible reward is not involved. A certain amount of psychology is also involved because, when a unit has been in operation for a certain period and happens to have been on one location during that period, an impression is gained that it is an "old" truck, hence, after it is overhauled, it is still considered an old truck, and the tendency is not to treat it with the care given a new truck. This probably is one of the most troublesome aspects that large operators must contend with.

I know of one case in which a truck, after having been completely overhauled, had not proceeded more than 3 blocks from the plant when it had to be towed in, the driver having made no allowance for the fact that the engine was practically the equivalent of a new one because of the work done on it, with the result that several of the bearings were burned out. I have often thought that, if the identity of units could be submerged, it would be a considerable factor in prolonging their life. Instances are on record of old trucks operating as economically as new models and by old trucks I mean those which have been in operation for more than 5 years.

Costs of Fleet Operation

In the discussion of a paper by R. E. Plimpton submitted to the Society and dealing with an analysis of the costs of 10 years of fleet operation, the statement was made[2] that it had been proved that a truck could be put into first-class operating-condition after from 10 to 11 years of service; furthermore, that one truck of a certain make had been in service for 5 years, and that, by using ordinary methods of repair and inspection, it was possible to keep it on the road until the end of 8 or 9 years before being compelled to buy a new truck.

Other instances of this nature could be cited to prove that, broadly speaking, the depreciation of a vehicle is directly proportional to the manner in which it is maintained. Such items as the types of road over which it operates and the service in which it is engaged must be taken into consideration, for they have a proportional bearing on depreciation; but the effects can be offset by a careful choice of equipment and by regular and systematic maintenance.

Inadequacy

The next consideration is that of a unit which becomes unsuited to or inadequate for the particular use assigned to it. This feature, perhaps, is one with which operators of small fleets are more frequently confronted, because those operating large fleets have greater opportunities for moving the units around; consequently, a unit that becomes inadequate in one place very often can be used to good advantage in another, thereby avoiding the necessity for disposing of it. Even large operators, however, find that certain units prove inadequate, and then the cheapest thing to do is to dispose of them. But careful analysis of the type of equipment purchased will offset the possibility of the occurrence of many instances of this kind.

Obsolescence

The remaining feature to be considered is obsolescence. The possibility of obsolescence is becoming more remote, because the trend is toward refinement of detail rather than drastic change in design. This remark, of course, refers to trucks and does not hold to the same extent in the case of automobiles. Builders for several years have followed the practice of making changes in their models gradually, hence, owners have been enabled to adopt these improvements without any drastic or expensive changes when the vehicles undergo repairs. Excluding light models, no radical changes in the design of trucks, such as would justify the disposing of the units in use, have taken place for several years. From present indications, moreover, it appears that no drastic changes are contemplated, hence, the possibility of current models' becoming obsolete is, so far as can be seen, remote.

If a builder should cease production, thereby rendering a particular model an orphan, it is a serious question whether the unit should not be disposed of as quickly as possible, because of the expense of acquiring repair parts; it is, however, inadvisable to retain in service units of this nature longer than the period during which an equitable exchange can be made for current models of other makes.

Improvements in Shop Practice

Another phase of the situation to be borne in mind is that of late years great improvement has been made in methods of shop practice, tools and certain accessories that can be placed on units, such, for instance, as air-cleaners, pressure lubricating-systems, shock-absorbers, cushion tires, and the like. These improvements can be added to any unit, when circumstances justify it, and their adoption has a tendency to reduce mechanical upkeep and to prolong life.

The foregoing statements will not hold for passenger

[2] See The Journal, September, 1924, p. 208.

cars, because certain features, such as changes in body design, improvements in riding-quality, and refinements in engine design that result in better operation, have an important effect on the public and produce more frequent trading-in of cars; therefore, the time in which any car can be said to become obsolete cannot be held as a criterion of truck operation. In one case, the general appearance of the unit and the individual taste of the owner govern, whereas, in the other, it is purely a matter of mechanical efficiency and cost of operation. A point, however, in the obsolescence of cars, particularly of the cheaper grades, should be taken into consideration.

Results of Operation

Fig. 1 shows the results derived from the actual operation of 387 automobiles of a cheap type over a period extending from 1919 to 1923, inclusive, the aggregate mileage amounting to a little more than 7,000,000 miles. The lower portion of the chart shows the annual cost per mile plus depreciation, as well as the same cost less depreciation. The figures for the first-year's cost of operation were obtained by taking the operating costs of all the cars in their first year, whether the models were of 1919, 1920, 1921, 1922, or 1923; the second-year's totals were obtained in the same way.

The cumulative cost per mile is, of course, the average cost per mile at the end of each period for the total mileage up to that time. In other words, the figure shown at the end of the fourth year is the average cost per mile of all the cars up to and including their fourth year of operation. The depreciation curve shown dotted is the method of depreciation employed by the company I represent. The solid line is a depreciation curve computed from the present trade-in values of cars to establish a comparison. It will be noted that the two do not differ much.

Time for Trading-in

In Fig. 2, the four curves shown at the top of the chart were drawn for the purpose of determining the logical time to trade-in a car for a new one or, in other words, to determine its economic life. The solid lines indicate the expense incidental to annual replacement; the dotted lines, the expense involved in annual repairs.

In the 5-year average, the costs shown indicate the average expense involved after taking into consideration the whole 5 years of operation. In other words, first-year operating costs represent the average for all cars in their first year of operation, the second-year operating costs the average for all second-year cars, and so on. The annual-replacement curve indicates the cost of replacing cars, taking as the price of a new car the average price of such a unit over the 5 years, and as the operating cost the average of all cars in their first year of operation.

It will be noted that at the end of the second year of operation based on these figures, the annual replacement-investment would be $939, whereas the annual repair-cost would be $937. At the end of the third-year period, the annual repair-cost would have amounted to $1,475, whereas the annual replacement-investment would have amounted to $1,409; consequently, it would have been economical to trade-in the car at about the end of the 2.5-year period; and, as the periods are based on an 8500-mile average, approximately 22,000 appears to be the logical mileage.

Operating Cost and Annual Replacement

In the 1919 models, the operating costs shown by the dotted line are from actual figures of these models,

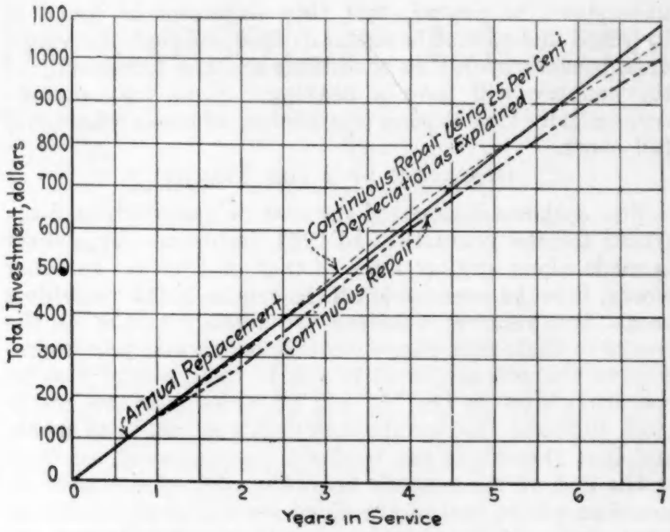

FIG. 4—CHART SHOWING COMPARISON OF CONTINUAL MAINTENANCE-COST WITH THAT OF ANNUAL REPLACEMENT FOR THE 2-TON TRUCKS MENTIONED IN FIG. 3

The Solid Line Indicates the Annual Replacement-Cost, Based on the Average Cost of First-Year Operation, Plus the Average Investment; the Dot-and-Dash Line, the Annual Maintenance-Cost, When the Depreciation Is Proportional to the Use the Unit Receives

whereas the annual replacement is obtained by taking the initial cost of the new unit at the end of each period at the exact price at that time. It will be noted that the lines cross after the beginning of the second year. In the 1920 models, however, the chart for which is drawn along lines similar to those for 1919, it appears that just before the second-year period would have been the logical time to trade-in; and the same remark holds good in the case of 1921 models. These figures are not submitted as proof of any theory but as an example of the information that we derived from making an analysis of costs over the periods mentioned.

Certain conditions have an important bearing on the costs that were beyond our power to control at the time, particularly during 1919 and 1920. These rendered the costs higher than they would be now; therefore, the period at which we deem it advisable to trade-in is advanced further. In other words, we believe that, in the average case, from 30,000 to 35,000 miles constitutes the economic life of this type of automobile. It is to be

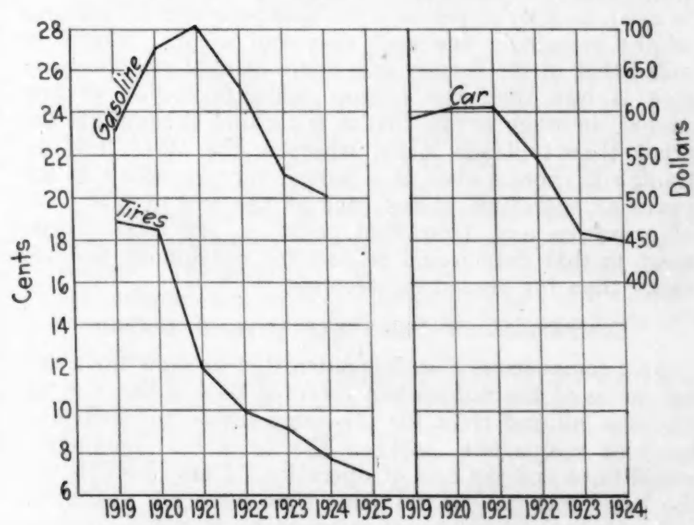

FIG. 5—COMPARATIVE PRICES OF CARS, GASOLINE AND TIRES

The Cars Are Those Mentioned in Fig. 1; the Fluctuations in the Prices of Gasoline and Tires on the Pacific Coast Are for the Period 1917 to 1923, Inclusive

understood, of course, that this statement is broad in its scope and cannot be taken as final for each individual unit, because operating conditions and the topography of the country will have a bearing. Some may operate economically long beyond this period, whereas others will fall short.

Operation of 2-Ton Trucks

Fig. 3 shows a chart of the cost of operation of 2-ton trucks for the years 1917 to 1923, inclusive. This chart is made along similar lines to that of Fig. 1. In other words, it is the average of all the trucks in the individual years, first year representing the average cost of all the trucks in their first year of operation, second year representing the average of all trucks in their second year of operation, and so on. It will be noted that the years 1919, 1920 and 1921 established peak periods, so to speak, and that thereafter the tendency is downward, so that, at the end of the seventh year, the cost of operation is less than at the end of the third year, if depreciation is eliminated. If depreciation, however, is taken into account, the cost at the end of the seventh year is less than at the end of the first year. This, of course, is accounted for by the fact that the depreciation is at the maximum in the first year and thereafter follows a gradually descending scale.

The depreciation curve is shown to establish the relative value of depreciation. A curve is also shown to indicate the cumulative cost per mile. Depreciation is not taken into consideration in this curve, which is given as a comparison of the annual cost per mile less depreciation, to establish a contrast between the figures obtained by taking the cost of any unit in a particular year of its operation and the cumulative cost up to that period.

Cost of Replacement and Maintenance

Fig. 4 is a chart prepared from the average cost of operation over the 7-year period mentioned. The solid line indicates the annual replacement-cost based on the average cost of first-year operation plus the average investment; the dot-and-dash line indicates the average annual maintenance, when the depreciation such as is used by this company is taken into consideration, in other words, the depreciation proportional to the use the unit receives; whereas, the dotted line indicates the expense over the same period when 25 per cent depreciation is used, that is, 25 per cent the first year and 25 per cent of the remainder the next year and so on. It will be noted that in the former case the continual maintenance-cost is less than the annual replacement-cost at any period; in other words, that it is cheaper to maintain the truck than to trade it in; whereas, the other line, although it crosses over at a period corresponding to 2.5 years of operation, comes back at the end of 5.5 years of operation and, from that point on, the total investment to that date would be less for continuous maintenance than for annual replacement.

Comparison of Price and Operating Cost

As a comparison, Fig. 5 is submitted to show the average price of the automobile referred to and the cost of gasoline, oil and tires for the same period to furnish a basis of comparison between the price the commodity would have and the cost of operation. Complete data on the labor cost during the same time were not available.

In the case of the truck referred to, it will be understood that the prices and charts shown are based on averages; the units, therefore, that cost excessively will militate against those that operate economically; hence, as a rule, the figures cannot be accepted but are submitted only as a result of the investigation for the period referred to. It must, furthermore, be borne in mind that the costs, both of cars and of trucks, include all charges such as painting, repairs due to accidents and the like, so that, from the standpoint of economic life, it is reasonable to assume that the accurate figures of any individual unit operating under average conditions would show better results, or, in other words, cheaper operating-costs, hence, longer economic life. Individual units can be picked out, of course, that will contradict the results shown above.

Conclusion

In the final analysis, therefore, although I am of the opinion that any truck built by a reputable company and properly maintained will have an economic life of at least 8 or 10 years, nevertheless, it is essential to take into consideration in each case the operating conditions; consequently, it is very difficult to set down any rule that will govern all cases. A well-defined theory may exist, but in practice it is necessary to analyze each individual case. As has been mentioned above, certain factors render difficult the determination of the economic life of passenger cars, except in the cheaper grades.

THE DISCUSSION

E. B. Moore[3]:—The cost of operation and the economic life of a truck bring out three points, (*a*) physical depreciation, (*b*) inadequacy of equipment and (*c*) obsolescence. Figures will not give a correct comparison of operating costs unless the trucks are used in the same line of business and for the same class of work. A set of figures was brought to my attention recently for which the same system of cost accounting had been used to find the shop costs of a number of different kinds of business. After deducting the cost of labor and materials, the overhead showed a variation of from 33 1/3 to 200 per cent, the smallest being taken from a fleet having a three-man shop and a working foreman. This shows that an honest record of one company would not be reliable for another.

Our own delivery-system cost should be considered by departments, the physical depreciation of the retail milk-delivery cars being entirely different from that of the wholesale. A retail truck making an average of about 300 stops per day is either starting or stopping every few minutes from the time it leaves the plant until it returns. This brings out some rather interesting figures. In a car using a gear-shift, the gears are shifted about 900 times a day or 27,000 times a month. This would equal several years' service of an ordinary passenger car; and every time a car is started it must be stopped, which shortens the life of the braking-system. I do not believe that an average gasoline retail milk-delivery car will ever reach the obsolescent age on account of physical depreciation.

With electric cars, conditions are changed. We have several cars that have been in continual service for 10 or 11 years. The present annual overhaul does not cost more than that of cars built 5 years ago. With the gasoline-driven 3-ton trucks in wholesale delivery, which have fewer stops, the cost per mile or per day is much less than with the 1-ton trucks. In the ice cream depart-

(*Concluded on p. 71*)

[3] M.S.A.E.—Superintendent of transportation department, Los Angeles Creamery Co.; manager, Los Angeles Automotive Works, Los Angeles.

Fundamentals of the Gasoline-Electric Drive

By E. M. Fraser[1] Cleveland Section Paper

ABSTRACT

Being inherently a constant-torque device, a gasoline engine needs some form of variable speed and torque transmission. In automotive vehicles, a friction clutch acting through a changeable-ratio gearset is used, the purpose being to increase the torque of the engine to obtain rapid acceleration and to enable the vehicle to climb hills and travel through sand and mud. But clutches and gears have objectionable features and, to overcome them, several types of gasoline-electric drive have been developed, the fundamental elements of which are (*a*) an electric generator connected with and driven by the gasoline engine and (*b*) an electric motor connected through suitable means with the driving-wheels of the vehicle. Inasmuch as control of speed and torque is obtained by varying the strength of the magnetic field of the motor and of the voltage supplied to the motor, this control is made automatic with changes of the speed of the engine and of the load on the vehicle by series windings on either or both the generator and the motor fields.

With a view to clarifying the method of operation of the gasoline-electric drive, the author expounds some of the fundamental principles upon which generators and motors are based.

The two principal objections to the use of electrical transmission in motorcoaches are (*a*) the excessive weight of the generator and the motor and (*b*) their high cost. This is due largely to the quantities of iron and copper that they contain. The horsepower of an electrical machine, however, is not dependent on weight. The size and weight are governed by the torque, which, in turn, is governed by (*a*) the magnetic flux, or the number of magnetic lines of force passing through the field-magnets, and (*b*) the ampere-turns of excitation of the armature. Doubling either the field flux or the armature ampere-turns will double the torque; if both are doubled, the torque will be squared.

Efforts to develop the necessary torque with a small light field and a light armature-winding composed of many turns have hitherto been impracticable because of the excessive armature reaction produced. The compensating winding invented by Professors Thompson and Ryan and the use of a commutating pole have served to diminish the field distortion but have not decreased materially the weight of the field, which usually is about 95 per cent of the total weight of the machine.

With a view to overcoming the handicaps of excessive weight and cost, the author, associated with A. L. Garford, has developed the Fraser Electro-Control Unit, which combines in a single unit all the functions of a generator and a motor.

The basic idea embodied in this unit is the use of only one field-structure for both the generator and the motor windings, which are placed concentrically outside of and enclose the field structure and rotate independently of one another. One armature is secured to the crankshaft of the engine and performs all the functions of a generator armature; the other, connected with the propeller-shaft, performs all the functions of a motor armature and drives the vehicle.

By eliminating one field-structure, the total weight is 47.5 per cent less than that of any electric drive using two complete electrical machines, while the fact that the two armature windings act as compensating windings for each other enables the size and weight of the field-structure to be reduced to the minimum without causing unstable operation of either the generator or motor-armature winding. The unit also performs in other ways, replacing the lighting generator, the starting-motor, the flywheel, the clutch, the gear transmission, and the service brake.

Figures as to acceleration, efficiency and cost of operation are included.

The need of an electric, or other form, of variable speed and torque transmission in connection with gasoline engines is occasioned by the fact that a gasoline engine is inherently a constant-torque device, in which the horsepower varies directly with the speed. I shall discuss more particularly the use of gasoline engines in automotive vehicles, such as passenger cars, motorcoaches and trucks.

In all automotive vehicles, the engine is first started and, while running, is connected with the driving-wheels by a friction-clutch acting through a changeable-ratio gearset, the purpose of the friction-clutch being to allow the engine to run at a greater speed than that of the propeller-shaft while the vehicle is getting under way. The purpose of the changeable gear-ratio is to increase the torque of the engine to obtain rapid acceleration while starting the vehicle, and to enable it to climb hills and travel through mud and sand.

Clutches and gears, although in general use, have certain objectionable features that are generally known. To overcome the various drawbacks inherent in clutches and gears, an electric-drive for use in connection with gasoline engines was conceived; and considerable work has been done in developing and building gasoline-electric drives.

The fundamental elements of any gasoline-electric drive are: first, an electric generator, connected with and driven by the gasoline engine; and secondly, an electric motor, connected through suitable means with the driving-wheels of the vehicle. The power of the gasoline engine is transformed wholly into electric power through the medium of the generator; the electric power is applied to the electric motor and causes it to drive the vehicle. The purpose of this layout is to control the electric current and cause a change of speed and torque between the gasoline engine and the driving-wheels of the vehicle.

Any electric motor, operating on direct current, can be made to change its speed and torque smoothly, gradually and noiselessly by the use of a simple controlling-mechanism. This characteristic of direct-current motors is the basis of the idea of using electrical machines for transmitting the power of the gasoline engine to the driving-wheels of a vehicle. Alternating-current motors are not susceptible of wide variations of speed and cannot be used for gasoline-electric drives.

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Control of Speed and Torque

The three practical ways of controlling or changing the rotative speed and torque of an electric motor are: (*a*) varying the strength of the magnetic field, (*b*) varying the voltage applied to the motor and (*c*) shifting the brushes on the commutator.

Another method of changing the speed of the motor is by introducing resistance into the armature circuit. This method does not increase the torque of the motor as the speed is reduced, is very wasteful of power and is not practical for use in gasoline-electric drives.

In controlling a gasoline-electric drive, in which the generator and the motor are always mounted on the same chassis, the first two methods of control are usually adopted. The voltage supplied to the motor by the generator can be varied by inserting resistance into the generator field-circuit. The speed of the motor can also be changed by inserting resistance into the motor field-circuit. Instead of field rheostats, a series winding can be used on either, or both, the generator and the motor fields. The control of speed and torque then becomes automatic with changes in the speed of the engine and the load on the vehicle.

The method of control by shifting the brushes on either the generator or the motor commutator is not feasible, owing to the violent and destructive sparking that is produced when the brushes are moved away from the neutral zone.

To understand the fundamental principles underlying any gasoline-electric drive, it is necessary to know something of the basic principles of generators and motors. When any electrical conductor is moved through a magnetic field or, as it is usually stated, cuts magnetic lines of force, an electric potential is created in the conductor. If the ends of the conductor are connected and form a closed circuit, current will flow in the circuit and force must be exerted to cause the conductor to pass through the magnetic field. Conversely, if an electric current is caused to flow through a conductor situated in a magnetic field, the conductor will move across the field, the direction of the movement depending on the polarity of the magnet and the direction of flow of the current.

Any electrical conductor in which a current is flowing is an electromagnet. It is well known that, if two simple horseshoe magnets are held with the two north ends together and the two south ends together, the magnets not only will not attract but will actually repel each other, and force is necessary to hold them together. It is also true that, if unlike poles are in contact, north with south and north with south, the magnets will attract each other and force must be exerted to pull them apart. In other words, the like poles of a magnet repel and the unlike poles attract each other.

Elements of Direct-Current Electrical Machines

The two essential elements of any direct-current electrical machine, whether generator or motor, are (*a*) a field-magnet and (*b*) an armature. A field-magnet, or electromagnet, is familiar to nearly everyone interested in radio. An armature is a more complex piece of apparatus. A direct-current armature consists of an iron cylinder called a core on the periphery of which are wound coils of wire, two sides of each coil lying parallel to the axis of the cylinder. The ends of each coil of wire are connected to bars in a commutator, on which brushes are held in rubbing contact.

Any armature is an electromagnet, for the reason that it is composed of conductors, each of which is a magnet when current is flowing, the magnetic intensity of the armature being the sum of the strengths of the individual magnets. The construction of the armature is such that its magnetic poles can remain stationary while the physical armature material revolves, or vice versa.

It has been pointed out that like poles of two horseshoe magnets repel and unlike poles attract each other; so, in a similar manner, it is the reaction between the poles of the field-magnet and those of the armature magnet that cause the generator to absorb power, when driven, and the electric motor to give off power, when electric current is supplied to it.

The two outstanding objections to electric transmission, so-called, in motorcoaches are: (*a*) the excessive weight of the two units and (*b*) which is co-related, the large cost.

I have heard the statement many times, that "there must be just so many pounds of copper and iron per horsepower-output in any generator or motor." Nothing could be farther from the truth. Some electric motors weighing 5000 lb. are rated at 50 hp.; others having the same weight are rated at 250 hp. In one case, the pounds per horsepower is 100; in the other, it is only 20.

Size and Weight Governed by Torque

Primarily, horsepower has nothing whatever to do with the weight of any electrical machine. The factor that governs the size and weight is the torque that is capable of being absorbed by a generator or of being exerted by a motor.

Two things govern the torque of any electrical machine: (*a*) the amount of magnetic flux or, technically, the number of magnetic lines of force passing through the field-magnets; and (*b*) the ampere-turns of excitation of the armature, ampere-turns being the product of the turns of wire and the amperes flowing in them.

The torque varies directly as these two factors; that is, doubling the field flux will double the torque, the armature ampere-turns remaining constant. Doubling the armature ampere-turns will double the torque, if the field flux is constant. Assuredly, if both the field flux and the armature ampere-turns are doubled, the torque will be squared.

The proportional total effective weights of the field, which produces the magnetic flux, and of the armature-winding, which supplies the armature ampere-turns, the two elements that govern the torque of any electrical machine, are roughly 95 and 5 per cent, respectively. These proportions are not arbitrary and may change, depending on the design and on certain operating-conditions; but these proportions usually prevail in electrical machinery adapted for use with gasoline-electric drives.

As previously stated, if the armature ampere-turns are doubled, the torque will also be doubled, with the same strength of field. Such being the case, why is it not possible to have a small light field and a comparatively light armature-winding composed of many turns, the armature-winding being made strong enough to develop the necessary torque, and thus obtain a very light generator or motor of large power?

Armature-Reaction

I will explain why this has not been practicable in the past. A fundamental law of physics is that action and reaction are equal and opposite in direction. Accordingly, when a motor armature exerts torque to produce power, an equal torque is exerted in the opposite direction. As the armature revolves freely in bearings and is not mechanically connected to anything except the driven load, the only thing that this reactive force can

be exerted against is the magnetic field, the ethereal thing we call lines of force, and not the physical field-structure. In doing so, the lines of force are pushed out of their normal path. This effect is called "armature reaction." To overcome this reaction has been the one big problem of electrical-machine designers and engineers since generators and motors were invented.

The greater the torque exerted by the armature, the more will the lines of force be displaced. If the torque is sufficient, the magnetic field will be completely displaced and the armature will cease to exert torque.

To produce a stable machine, the magnetic field must be made very strong as compared to the armature ampere-turns. This is the reason that the first is made so massive and heavy as compared to the armature-winding, and the reason that it has not been practicable to increase the armature ampere-turns indefinitely.

During the years in which electrical machinery has been in course of development, inventors have found several ways to overcome, or neutralize, armature reaction. One way, invented by Professors Thompson and Ryan in this Country, is to surround the armature with a winding similar in character to that of the armature-winding. This winding is connected in series with the armature circuit and the main current is caused to flow in the "compensating" winding in a direction opposite to that of the current in the armature-winding. This winding completely and effectively neutralizes all armature reaction, and it is possible to obtain stable operation at all loads and at widely varying speeds of rotation.

Unfortunately, this added winding is so large and takes up so much space that, as a general thing, the total weight of the machine is not reduced and the cost usually is increased, due to the added complication. Consequently, this winding is used only in special cases, such as in adjustable speed motors or high-speed generators. It is not to be considered in connection with gasoline-electric drives.

Commutating Poles

Another scheme to obviate the sparking at the brushes caused by the armature reaction is to place small magnets in the neutral zones between the main poles. These magnets, or commutating poles, as they are called, prevent sparking under widely varying conditions of speed and load but tend to increase, rather than diminish, the field distortion. They do not decrease the weight of the field structure materially. Commutating poles are used in connection with electrical apparatus as used for gasoline-electric drives.

Several gasoline-electric driving-systems for automotive vehicles have been developed and marketed in the last decade. One of the best known for motorcoach work is the Tilling-Stevens, which is made and used in England. This company has operated motorcoaches successfully in London for the last 15 years. The General Electric Co. now has in course of development a gasoline-electric system for motorcoaches, a number of which are in service.

The most widely known gasoline-electric drive developed in this Country is the Owen-Magnetic, or Entz, system, which is not strictly an electric transmission, or drive, but is an electromagnetic clutch. With this system, it was not practicable to reverse, so a reversing gear was used and, to keep down the weight of the electrical units, a low gear also was added to enable the vehicle to climb steep grades.

In all gasoline-electric driving-systems that have been tried out and are operating to date, the great drawback, as previously stated, has been the excessive weight and cost of the electrical units. To save weight, efficiency has been sacrificed, and electric drives have not been able to show the economy that would be possible if it had not been necessary to curtail the weight. Notwithstanding these serious handicaps, electric drives on motorcoaches now running show marked economy of operation and upkeep, as compared to similar vehicles equipped with gear transmissions.

Fraser Electro-Control Unit

To overcome the great handicaps of excessive weight and cost and to obtain all the advantages of the electric drive I became associated with A. L. Garford of Elyria, Ohio, and, after 10 years of research and experiment, have developed what is called the Fraser Electro-Control Unit.

Notwithstanding the fact that a gasoline-electric driving-system includes a complete generator and a complete motor, the Fraser Electro-Control Unit, on the contrary, is a single unit that performs all the functions of a generator and a motor.

The basic idea embodied in the Fraser Electro-Control Unit is the use of only one field-structure for both the generator and the motor windings. Imagine a conventional-type armature, having the iron core removed and only the winding left. The winding would then form a hollow cylinder. A field structure is then placed inside this winding and prevented from rotating. Another similar armature-winding is slipped over the outside of the first winding and the enclosed field. Outside of both windings and field is a soft iron or steel casing that forms the return path for the magnetic flux. Both armature-windings are free to rotate independently of one another. One armature is secured to the crankshaft of the engine and performs all the functions of a generator armature; the other is connected to the propeller-shaft, performs all the functions of a motor armature and drives the vehicle.

The fact that one complete field-structure is eliminated reduces the total weight to 47.5 per cent less than that of any electric drive using two complete electrical machines, each field-structure in the conventional drive being about 47.5 per cent of the total weight of the apparatus.

It has been stated that armature reaction is the principal cause of the excessive weight of the field and that a compensating winding, such as the Thompson-Ryan, will completely neutralize this reaction. Such being the case, the two armature-windings contained in the Fraser Electro-Control Unit act as compensating windings for each other. It is possible, therefore, to reduce the size and weight of the field structure to the minimum without causing unstable operation of either the generator or the motor armature-winding.

Saving of Weight

In one unit built and operated in a Cadillac Model-57 phaeton, the field system was 53 per cent of the total effective-weight, the armature-windings, 47 per cent of the total effective-weight. These figures mean that a Fraser Electro-Control Unit weighs only 20 per cent as much as similar-powered driving-apparatus that consists of two complete electrical machines. It can thus be seen that a way has been found to reduce the excess weight of the field as compared to that of the armature-windings, and to reduce to a practical figure the total weight of the electrical machine necessary for a gasoline-electric drive.

The Fraser Electro-Control Unit is so named for the

reason that it performs in other ways, in addition to acting as a variable speed and torque transmission. The unit replaces the lighting generator, the starting-motor, the flywheel, the clutch, the gear transmission, and the foot brake.

The Fraser Electro-Control Unit is controlled by a simple field-rheostat. A speed and a torque can be had in the ratio of 6 to 1. The engine torque can be increased three times for acceleration and hill-climbing, and 100-per cent overspeed can be obtained in high gear. Nothing is inherent in the unit that will limit the range of the speed and the torque. Experience has shown that such a range of speed and torque is ample to provide for all the usual operating-conditions.

During the last 10 years, a number of these units have been built and tested in well-known makes of car. The weight per horsepower output of one of these units installed in a Cadillac Model-61 phaeton is 3 lb. per hp.

Efficiency of the Electric Drive

In discussing gasoline-electric drives, I am always asked one question: What is the efficiency of the electric drive? If I say anything less than 100 per cent, the retort usually is: The electric drive then can never be so efficient as the gears when in high, for the reason that, when in high, the engine is connected directly to the propeller-shaft and no loss occurs in the transmission. This is not a true statement, for some of the gears are always in mesh, even in high, and a certain loss from friction and from grease resistance always occurs.

Though it may be granted, for sake of argument, that the efficiency of the gear transmission in high is 98 per cent, and that the efficiency of the electric drive in high is 80 per cent, this does not necessarily mean that the electric drive will use 18 per cent more power and 18 per cent more gasoline to run the vehicle. It is a fatal mistake to compare the efficiency of a gear transmission, as an entity, with the electric drive, as an entity. They cannot be compared any more than a lobster can be compared with an apple. The only proper way is to compare the over-all efficiency of the vehicle, when equipped with the gears, with the over-all efficiency of the vehicle when equipped with the electric drive.

Running at Most Economical Speed

In a vehicle equipped with gears, the gasoline engine hardly ever runs at its most economical speed. On the contrary, in a vehicle properly equipped with an electric drive, the engine can always run at its most economical speed. This is due to the wide range of speed and torque control to be had with the electric drive. Thus, it is possible to operate a vehicle with less horsepower and less fuel, with an electric drive of lower transmission-efficiency than with a gear transmission.

To illustrate, I will cite figures obtained from tests made on one of the most popular makes of car, which was equipped with a gear transmission and, when running at 30 m.p.h., required 6 hp. to overcome the friction of the engine. The horsepower required to run the car on a level road was 10, making the total horsepower 16. It is assumed that the efficiency of the gear transmission is 100 per cent and that no loss occurs in the gears.

A properly designed electric-drive will give an overspeed of 100 per cent in high. In other words, the speed of the engine is only one-half as great with the electric drive as with the gear transmission at the same car-speed. Let us see what horsepower will be required to run the same car at the same speed with the electric drive. It is safe to assume that the efficiency of the electric drive is 80 per cent. At the reduced engine-speed, the horsepower required to run the engine is only 1.5, the horsepower required to run the car being the same as before. To this we must add the loss due to the electric drive, which, at 80-per cent efficiency, will be 2.5 hp. The total horsepower required to run the vehicle is 14, a saving of 2 hp., or 12.5 per cent. This saving does not take into account the greater fuel-efficiency of the engine when running at a lower speed and a higher compression. These figures show that an electric drive with lower unit-efficiency than that of gears will give much higher over-all car-efficiency.

The electric drive has another advantage, that is, the ability to coast freely when descending grades or when the vehicle is slowing-up and stopping. In this way, the vehicle can be run at high speed with the engine idling, and much wear and tear on the engine, also fuel and lubricating oil, can be saved. Road tests have shown that because of this ability to coast freely, and without effort and annoyance to the driver, the car mileage per gallon of fuel has been increased from 50 to 100 per cent.

Wear and Depreciation

In motorcoach and truck service, the wear and depreciation on clutches, gears and brake bands are very great. If for no other reason than to save the wear and up-keep of these parts, an electric-drive will justify itself. Records kept by the Fifth Avenue Coach Co., of New York City, show that the cost of material for brake-linings alone per motorcoach per year is $150. The labor of replacing the lining is not included in this amount.

Records kept by the Tilling-Stevens Motors, Ltd., Maidstone, England, over a period of years, show that gasoline-electric-driven motorcoaches operate at a cost of $0.05 per mile less than gear-driven motorcoaches in the same service. These records also show that the average distance run per breakdown for the gear-driven type of motorcoach was 13,450 miles, as compared with 108,693 miles for the gasoline-electric-driven motorcoach.

Originally an armature was a piece of soft iron that acted as a collector across the poles of a horseshoe magnet. When electrical machines were invented, this piece of soft iron was made round and covered with wire. Primarily, the iron alone was the armature. Armatures used in electric control-units originally had teeth, and the only thing left was the iron between the conductors. Through tests and experiments we found that the iron was a detriment. Our latest type of armature does not contain iron. The iron has been eliminated completely, and only copper remains in the armature. We also have abandoned the name "armature" and, because the conductors, or the windings on the armature, contain an induced voltage, the structure is called an "inductor." The inductor has been lightened very materially by eliminating the iron.

In a Cadillac Model-61 phaeton that has covered 4000 miles in the hilly country of Westchester County, N. Y., the engine furnished the power and the motor-inductor unit drove the car up an 18-per cent grade at 24 m.p.h., and the car could be braked so that the wheels would slide in going down the grade. The inductor, with the commutator, weighs only 37 lb. The engine is rated at 35 hp. at 3500 r.p.m. The inductor has been tested with a Sprague dynamometer of 1000-lb-ft. torque. In fact, during one of the tests with this particular unit, the knife edges of the dynamometer that registered the pressure were sheared off. It showed a 500-lb-ft. maximum satisfactorily and we do not know how great the pressure was.

Most engineers object to an inductor made without an iron support for the windings. They cannot conceive of a winding sufficiently strong that is made in this way. They think it will fly apart and will not remain round, which is very natural. I, too, thought this true at one time.

Use of Bakelite and Condensite

The thing that made this type of winding possible is the invention and development of synthetic varnishes, like Bakelite and Condensite. Prior to that time, all varnishes would soften from the effect of heat. They were not permanent. Linseed-oil varnishes would absorb oxygen, swell up and disintegrate. But these permanent varnishes are strong and perfectly good insulators and have made possible a new type of winding.

The windings are wound on a false core and are impregnated with Bakelite varnish. The core is then removed, leaving a cylinder of copper wire imbedded in Bakelite insulation, which is very strong. These windings have been subjected to considerable stress in driving a Cadillac car up-hill many times, but show no strain.

The conventional type of commutator was a cylinder. On the first drive that we built, we had one cylinder commutator and also a disc commutator. The first method used for controlling the transmission was to put a multiple winding on the armature and to couple the windings in series and multiple. This would change the speed and torque. Subsequently, we used a type of disc commutator that had different rows of bars and several circuits.

It was not so convenient to make the connections with a cylindrical commutator. We found that on this particular unit, which we put on an old Chalmers car, we had practically no trouble with the disc commutator but we had considerable trouble with the cylindrical type. It would get out of shape and the vibration of the engine would tend to throw the brushes out of alignment unless they were held in place with very strong tension. The disc commutator, with the brushes on the side, endured very well, and the radial vibration had no effect; so, we have adopted the radial type of commutator.

This commutator has the virtue of being very light, is cheaply made and is very durable. It is simply a steel disc or, as in the latest ones, an aluminum-alloy disc to which the bars are riveted. Holes are drilled in the disc and are bushed with mica tubing and mica plate. On the back of the armature is the driving-plate which is connected with the shaft that drives the propeller-shaft.

Arrangement of Armatures and Field

Inside the armature-winding is placed the six-pole field. The armature-winding has a 13-in. bore and the diameter of the field is 1/16 in. less. The clearance is about 1/32 in.

Outside the armature-winding is another similar winding, just large enough so that it will enclose the armature-winding, the distance between them being ⅛ in. The purpose of so large a gap is to prevent the armatures from rubbing when they get warm, or one warmer than the other. In addition, the outside winding is connected to the engine, so that in case of looseness or misalignment, it might rub. Outside the outer winding is a soft-iron ring that carries the return magnetic-flux.

In the armature that is installed in a Willys-Knight car, the field has four instead of six poles. We have found that in the small units, it does not pay to make too many poles. The saving in weight is offset by the cost of the added complication, so that the four-pole unit was decided upon as being the most practicable.

THE DISCUSSION

A Member:—In designing his machine has Mr. Fraser had any experience in using iron in the two armatures? He mentioned that there was no iron in them. Could not the machine be made lighter by placing iron in the armatures, so that the flux in passing from one field to the other would not require the same ampere-turns?

E. M. Fraser:—My system of air-gap is one that most electrical men abhor. The actual air-gap in any electrical machine, that is, the distance between the pole-pieces and the tops of the teeth, is very small. The area of the air-gap is always small and always less than the area of the pole-piece, depending upon the width of the teeth and the space between the teeth and the face of the pole-piece. So, that being the case, a large number of ampere-turns are required to force the flux across the narrow air-gap.

Another thing that causes an excessively strong field and a large number of ampere-turns is that the iron in the teeth is saturated and becomes just like air, when the motor is overloaded or a light-weight motor is designed to give heavy service. As the teeth are always saturated, an excessively large number of ampere-turns are required. In designing electrical machinery for motorcoaches, all the material must be used, the iron in the teeth must be saturated, and a large number of ampere-turns must be used in the field to overcome the air-gap. The air-gap is restricted, due to the area of the teeth and the saturation. When the armature is constructed with iron in the core, the winding is fairly deep, and the iron path through which the flux is carried is comparatively long.

We have built five units, each of which has iron teeth between the windings. There is no so-called iron core, for we found that the use of iron was objectionable. It was noisy and produced a hum. Another objection was that, as the flux leaked through the conductor, we were obliged to put more iron into the field, which added to the weight of the copper and to the resistance. All these things increased the weight so that we had a large field-coil that was inefficient.

The conventional way of building electrical machinery is to place the armature on the inside and the field outside. The armature is very small compared to the diameter of the field. In designing electric transmissions during the last 10 years I have reversed the usual procedure and have placed the field on the inside and the armature outside. The reason is that the armature diameter very materially increases the pole area. With the normal air-gap and a flux of 50 to 60 megalines, the windings were formerly 1 in. thick but, as the flux of the electrical control unit is from 20 to 40 megalines, the windings are only ⅜ in. thick and the two take-up only the space of one winding of the area of the teeth.

The objection to using a large armature and putting the field on the inside would be that an iron core made with laminations must be used; and a laminated sheet-iron core is comparatively expensive. It is desirable to keep down the size of the laminations and the cost of the dies for punching them. It is also desirable to keep down the iron loss, for this varies in proportion to the quantity of iron.

By eliminating the core completely we eliminate the cost of the core; and the outside winding is not objectionable from the standpoint of cost, that is, the cost of the sheet-iron core is not increased. So, due to these factors, namely, increasing the area of the poles and reducing the total path from pole to pole, the ampere-turns in the field are not increased.

As a matter of fact, we have four complete units, two with and two without iron, and the ampere-turns in both cases are approximately the same. As we have only one field instead of two, the field seems very efficient. It takes practically twice as much copper to wind two fields and, by adding a very small percentage of ampere-turns, the flux can be forced across a somewhat longer air-gap, which includes two rotors instead of one.

M. R. WELLS[2]:—Has Mr. Fraser had any experience or trouble with excessive heating of the motors on long mountain-climbs?

MR. FRASER:—Heat is always developed in electrical apparatus when it is delivering power; but we have not been troubled with excessive heat. This type of unit is constructed so that the radiating surface is very much greater than that of the ordinary type of armature; the armature is completely surrounded with air, and the coils have air practically on two sides. In the conventional type, in which the inductors are wound in slots, the only way in which air can get in is through the slots, and they are plugged up with wooden wedges. The core loss also adds to the heat. The conventional type of core has slots that serve as ventilators, but the area of these ventilating slots is small as compared with that of the hollow-type armature, and the slots are placed on the outside instead of the inside, so that there is greater facility for radiating the heat. Then, too, the winding itself acts as a fan in circulating the air.

MR. WELLS:—Do I understand that the windings of the armature are on the inside and the outside diameters with no drum to support them?

MR. FRASER:—They are supported at each end, on one end by the commutator and on the other end by a spider.

MR. WELLS:—There is no shell?

MR. FRASER:—No. There is an air space between the shell and the armature, and there is room between the windings and the inside and the outside of the windings.

MR. WELLS:—But there is no shell on the armature proper?

MR. FRASER:—No. They are held in place by the Bakelite impregnation; the commutator is made of such shape that no mica is used between the bars. The air space is approximately 1/16 in.; the air acts as an insulator and also serves to keep the dust and dirt from collecting between the bars. In an ordinary commutator, in which there is nothing to prevent the dirt from collecting, a great quantity of it collects, but the radial type of commutator will run a longer time without having to be cleaned, and then can be cleaned perfectly with a jet of air.

We made some comparative acceleration tests with a mechanically driven Willys-Knight sedan and with the gasoline-electric transmission, the results of which are shown in Table 1.

The custom is to make acceleration tests on gearshift cars by starting at 5 m.p.h. to avoid shifting the gears, because the time consumed in shifting the gears in starting a dead car adds to the acceleration time. I contend that this is the wrong way to make a comparison because, with the gasoline-electric drive, there is no shifting of gears. To bear that out and to show that the gasoline-electric-driven transmission will give greater acceleration in starting the car from rest, to accelerate the car to 5 m.p.h. required 2.4 sec.; to 20 m.p.h., 7.8 sec.; and to 25 m.p.h., 12.0 sec. The car was accelerated from a standstill to 30 m.p.h. in 18 sec., whereas the car with the gear transmission required 21 sec.

[2] M.S.A.E.—Research engineer, Cleveland Automobile Co., Cleveland.

TABLE 1—COMPARATIVE ACCELERATION TESTS OF A WILLYS-KNIGHT SEDAN

Speed, M.P.H.	Time Required To Accelerate from a Speed of 5 M.P.H., Sec. — Mechanical Transmission	Gasoline-Electric-Driven Transmission
20	10.20	10.20
25	15.00	13.20
30	21.00	19.80
35	33.00	31.20
38	....	37.80

The statement that a car can be accelerated, by an electric drive, in less time from rest than from a running speed of 5 m.p.h. may seem absurd. Practically all the engineering talent engaged in automotive development think the whole electric-drive matter is absurd. This is due, in a large measure, to reluctance to give the electric drive the same careful thought that has been given to the mechanical drives now in vogue; at least, that is the attitude I encountered in my work during the last 10 years in developing and testing an electric drive for automotive vehicles.

The first mentioned statement is not only not absurd but is absolutely correct, as I will now explain. In all efficiently designed gasoline-engines, the horsepower delivered by the engine, or capable of being delivered by the engine, varies directly as the speed. In the case of the Willys-Knight engine, as installed in the car spoken of in the acceleration tests, the brake horsepower, taken from actual dynamometer-test curves, at 500 r.p.m. is 10.0 hp.; at 1000 r.p.m., 20.4 hp.; and at 1500 r.p.m., 29.6 hp. With three times the engine speed, the engine delivers approximately three times the horsepower. At 5 m.p.h., the Willys-Knight engine is capable of delivering only 4.5 hp., when the axle gear-ratio is 5.12 and the tires are 33 in.

In conducting acceleration tests, it is required that the car be run at an even steady rate of 5 m.p.h. Under such conditions, whether a gear or an electric drive is used, only the maximum of 4.5 hp., taken from the test-curve, is available to accelerate the car. If it takes that amount of power to run the car at 5 m.p.h., the car will not accelerate; if less, the rate of acceleration will be entirely dependent on the surplus power available.

The maximum power available in the Willys-Knight engine is 37.8 hp. Notwithstanding that this large horsepower is available for acceleration, we are arbitrarily limited to 4.5 hp., solely by the fact that shifting gears has heretofore been the only way of changing the speed of the engine relatively to the speed of the wheels. Measuring the performance of the electric transmission by gear standards, the electric transmission is allowed only 4.5 hp. with which to start the car.

Eliminating this absurd condition and taking advantage of the extreme flexibility and control inherent in the electric drive, we have, when the car is standing still, horsepower available to the amount of 37.8 instead of 4.5. On operating the electric control so that the car begins to move, we have at our command always the maximum horsepower of the engine, plus the force contained in the rapidly moving parts of the engine and the electric drive. Instead of having to accelerate the parts of the engine with a small amount of power, we have the stored-up energy of the moving parts, in addition to the maximum power of the engine, to help accelerate the car.

It can readily be seen that, with 37.8 hp. available when the car is at rest, as against 4.5 hp. available when the

car is moving at a speed of 5 m.p.h., it is not only possible but is a fact that the acceleration time is less when starting the car from rest than is the time required to accelerate the car from and at 5 m.p.h.

COST OF OPERATION AND ECONOMIC LIFE OF MOTOR TRUCKS

(*Concluded from p. 64*)

ment, in which we also use 3-ton trucks and in which the routes compare with the wholesale milk department m stops and mileage, the physical depreciation is about double that of other departments on account of the salt water, which causes continual freezing of brake-levers, gear-shifts and spark and throttle controls, and oxidation of the frame and other metal parts. This is a source of continual expense for labor and the renewal of parts.

The obsolescence of a truck depends as much on the factory or agency that sells the equipment as on the truck itself. If it is possible to secure repair parts without having to send to an Eastern factory or to have them specially made, the loss of service of the truck will be lessened and its profitable life, therefore, will be lengthened. Our records show that the annual cost of operating some of our equipment that is from 7 to 9 years old is no more than that of other trucks of the same make that is 2 or 3 years old. A time comes, of course, when a truck reaches old age, and the fatigue of the metal becomes evident. This is the time when a truck should be "pensioned," but each case should be treated individually. Why should all cars be grouped and a date set for their retirement? The accidents they have been in, the drivers they have had and the service they have given should determine the age of obsolescence.

As to the inadequacy of a truck, more care should be given to the purchase of proper equipment in the first place. We see trucks in service every day that no builder could conscientiously recommend for the work they are doing. For instance, a truck of 4000-lb. rated-capacity is purchased. To it are added larger tires and heavier springs, and the frame is trussed. On this truck, 5 or 6-ton loads are carried. The truck is certainly inadequate for such loads and physical depreciation sets in immediately. Our company endeavors to replace a truck with one of larger capacity, if a route develops overloads; or the route is divided to keep the loads down to the rated capacity of the trucks.

Improvements to or new designs of trucks made in the last 8 and 10 years do not warrant retiring an older model truck for those reasons, but business conditions frequently change so that a truck must be transferred to other work or disposed of and another secured to fit the new conditions of the work. About 12 years ago, we had work for a truck such as we were unable to buy, so we designed and built it, then changed the design slightly and built two more. We now have 64 of this style and capacity in operation. We were told by the builder that we should have to make the business fit the truck, but we found it more profitable to make the truck fit the business. I believe that builders listen to the users of trucks more today and try to meet their needs.

In summarizing, I will say that we give the personal factor an important place and feel that the ultimate success or failure of the motor equipment of a fleet operator depends upon the knowledge and good sense exercised by the organization. The retirement of a vehicle depends upon its design, the use to which it has been put, the system of inspection and maintenance, the driver, and the roads upon which it has been used. Effort should be made to have the driver realize that he is in charge of a valuable tool and that he should take pride in its service and appearance.

Better governors should be built into all engines, not added as an accessory, and the speed should be kept down to a reasonable rate. The speed laws made for trucks are rarely enforced, 5-ton trucks being expected to keep up with the general traffic on the road. We feel that the success which we have had with electric trucks that do not need a governor, for they can only run at a maximum of 16 m.p.h., is due largely to their controlled rate of speed.

Too much cannot be said regarding the greasing of trucks. This work is usually assigned to the lowest-paid man in the plant and means a continual turnover of oilers. Almost as soon as a man becomes familiar with the location of all the oil and grease-cups, he leaves or is promoted to a better position. The name of this work should be changed from greaser to something more appealing and the work should be paid for according to the responsibility that it bears. The performance of many vehicles is subject to this man's care, and the work of a poor mechanic is soon apparent, for it can be quickly and easily traced before much damage has been done.

The unit-repair system and standardized fleets are big factors in keeping down operating cost. Special shop-tools can be maintained and mechanics trained to a higher degree of efficiency with standardized units.

THE JUDICIAL

A COMMON failing of naïve and inexperienced thinkers is the making of hasty and loose generalizations. Those who form the habit of measuring the length and breadth of their assertions avoid making sweeping universal statements that are not warranted by the actual facts, and for this reason their opinions carry more weight. They are said to be more judicial.—Prof. D. S. Robinson.

Discussion of Papers at the 1926 Annual Meeting

THE discussion following the presentation of four of the papers at the 1926 Annual Meeting of the Society held at Detroit is printed herewith. The authors were afforded an opportunity to submit written replies to points made in the discussion of their papers and the various discussers were provided with an edited transcript of their remarks for approval before publication.

For the convenience of the members a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared so that members who desire either to gather some knowledge of the subjects covered without referring to the complete text as originally printed or to refer to the illustrations that appeared in connection therewith can do so with the minimum effort.

THE ATTENDU HEAVY-OIL ENGINE

BY ANDRE C. ATTENDU[1]

ABSTRACT

EFFICIENCY of the Diesel engine, on the first development of which in France the author worked, and the possibility of using the low-priced by-products of gasoline production, led to the designing and building of several experimental engines of small size and low weight to run on fuel oil and develop the power required for average automotive work. The theoretical and commercial requirements that established the basis on which these engines were designed and built are enumerated and each type of engine is described.

The first engine, which was built in 1921 and given its first test-runs in 1922, was a four-cylinder two-cycle engine operated on the air-injection straight-Diesel principle. Scavenging air was supplied by step cylinders and the injection air was supplied at a pressure of 1200 lb. per sq. in. by a small compressor built integral with the engine. The engine compression-pressure was 300 lb. and the fuel used was fuel oil of from 18 to 22 deg. Baumé gravity. This engine weighed 1100 lb. and was expected to develop 40 hp. at 1600 r.p.m., but in test-runs it ran at 1300 r.p.m., developed from 36 to 38 i.hp. and only 11 b.hp., and consumed nearly 2 lb. of fuel per b.hp. It was hard to start and oxidation of the fuel by the injection air caused the valves to leak. Nevertheless, it ran and was fairly flexible under load from 300 to 1300 r.p.m.

Tests of this engine made at McGill University gave results that led to the decision to build a second experimental engine, substituting solid-fuel injection for air injection to eliminate the air-compressor, the intercoolers and the oxidizing effect of air on the fuel. This also was a four-cylinder engine, made of cast iron and having a compression pressure of 405 lb. The step cylinders for scavenging were retained and it operated on the same fuel as the first engine. In preliminary runs, the engine started on the first few revolutions, attained a speed of 1600 r.p.m. and developed 18 b.hp. Scavenging pressure was found to be too high and was reduced to 14 lb. Two transfer valves were substituted for the single valve and the rotary valves of the working cylinders were changed to poppet valves. To give better scavenging, the compressors, which originally discharged directly into the working cylinders, were connected to a common reservoir in the engine jacket and each working cylinder was scavenged with air from the reservoir. After these changes, the engine developed 46 b.hp. Changes in the fuel-pump and injector adjustments increased this to 56 b.hp. at 1400 r.p.m. Fuel consumption of the engine is at the rate of 0.76 lb. per b.hp. at from 1200 to 1400 r.p.m. and 0.87 lb. per b.hp. at 600 r.p.m. The engine idles down to 120 r.p.m. and starts readily from dead cold after three to five revolutions with a 6-volt starter.

Three engines of this type were built and a car fitted with one was operated about 3000 miles in the summer of 1924 without the slightest trouble. Two-thirds of this distance was run on a dirt track at an average speed of 27 m.p.h. and the fuel consumption was at the rate of 1 gal. per 19 miles. The car, fully loaded, weighed 5100 lb.

In August, 1924, a contract was secured from the Navy Department by the Eastern Engineering Co., Ltd., of Montreal, for the building of a two-cylinder experimental engine to determine whether a light-weight heavy-oil engine suitable for airship work would stand the high compression-pressures at high speed. This was built to operate on the same principle as the four-cylinder engine and designed to develop 100 hp. at 1500 r.p.m. or 125 hp. at 1750 r.p.m. and to have a weight of 3.8 lb. per b.hp. The only change in design is that the air-compressor is on the side of the engine and the pistons of the working cylinders are of standard trunk design.

The aviation engine was delivered to the engine-testing laboratory at the League Island Navy Yard in February, 1925, and after several tests and improvements on adjustments, especially on the lubricating-oil system, showed a brake-horsepower output of 85 at 1620 r.p.m. In the builder's own laboratory, however, an output of 91 b.hp. at 1525 r.p.m. has been obtained and it is foreseen that, by making some alterations that are now in progress, an additional output of from 20 to 25 b.hp. can be obtained, thereby bringing the engine up to 110 or 116 b.hp. for a total weight of 417 lb., or 3.6 lb. per b.hp. Fuel consumption is now in the neighborhood of 0.6 lb. per b.hp-hr. and it is expected that this can be reduced to 0.5 lb. per b.hp-hr. The maximum recorded speed is 2210 r.p.m.

A complete detailed description of this engine is given in the paper and the author states that tests made with it definitely establish the facts that light metal can be used in the construction of heavy-oil high-speed engines and that this type is no more difficult to build than the present type of gasoline engine. From comparative data obtained by the running of the small four-cylinder engine and the experimental two-cylinder aviation engine, the design of engines of any size and with any number of cylinders can be calculated with close approximation of the results to be expected.

[1] M.S.A.E.—President, Eastern Engineering Co., Ltd., Montreal, Canada.

Possible applications of this type of engine include trucks, motorcoaches, rail-cars, airships, tractors, pleasure craft and tugs with a low cost of power production that could not be dreamed of with the gasoline engine. —[Printed in the February, 1926, issue of THE JOURNAL.]

THE DISCUSSION

A MEMBER:—When it is considered that the average Diesel engine used today—on shipboard, for stationary powerplants and for locomotives employing electric transmission—weighs in the neighborhood of 100 lb. per hp., the advance that Mr. Attendu has made in building and operating a heavy-oil engine that weighs less than 4 lb. per b.hp. will be appreciated. Unquestionably, in due time, we shall have to operate all our automobile, marine and airplane engines on much heavier fuel than we are now using; hence, we owe a great debt to pioneers like Mr. Attendu who are laying the groundwork for such engines. Even today, in aircraft work particularly, the use of heavy fuels is very desirable as a safety measure. Fire spreads with terrific rapidity in an airplane, to extinguish it, once it has started, is practically impossible and, generally, the only recourse is to jump overboard. In lighter-than-air work the relative safety of helium gas with gasoline fuel versus hydrogen gas with a heavy fuel that has a much higher boiling-point than gasoline has been discussed at some length. The combination of helium, an all-metal ship and a heavy fuel represents the ideal. The Navy Department had these facts in mind, of course, when it sponsored the development of the particular engine that Mr. Attendu has described, and I think we should recognize that the Navy Department has done very creditable work in sponsoring this development, which necessarily has taken a great sum of money.

AIR-PRESSURE AND FUEL INJECTION

QUESTION:—What air-pressure is maintained by the compressor?

A. C. ATTENDU:—The pressure varies slightly with the engine-speed. At 400 r.p.m. it is in the neighborhood of 11.0 to 11.5 lb. per sq. in., and at 1600 r.p.m. it may run up to 13.5 or 14.0 lb. per sq. in.

QUESTION:—How is the fuel injected?

MR. ATTENDU:—The automobile engine has a two-stage solid-fuel-injection pump. The first stage creates preliminary pressure in the whole circuit, being approximately 800 lb. per sq. in., which is the pressure of the aviation engine in the first stage. The pressure-pump works right up to the tip of the injector, which has a double control, the same as a carbureter. It has a slow-speed and a high-speed adjustment. As a result of various tests carried on for about 6 years and of experience with Diesel engines in the last 20 or 21 years, we decided that the best pressure we could employ for the time being, which would not be too high for the pump to maintain, was about 6000 lb. per sq. in. on the oil. We found, however, that if we used 6000 lb. per sq. in. at from 100 to 200 r.p.m., the pressure would jump to 20,000 lb. per sq. in. when the engine was running at full load and speed. This was not satisfactory because then the oil would go into the engine cylinder in a solid jet and only part of it would burn while the rest would be a total loss and cause the engine to smoke. It also caused a great loss of efficiency and, in certain cases, would stop the engine completely. Therefore, I designed a new injector with double-spring control. The springs are calculated so that the lower spring serves as a slow-speed adjustment and is able to retain a pressure of 6000 lb. per sq. in. As soon as the pressure exceeds this figure, the needle-valve is lifted against the second spring and increases the area of injection for the fuel in the cylinder. If we inject, for example, 1 cu. in. of oil at 400 r.p.m., we must pass-in about 3 cu. in. of oil at 600 r.p.m., which we do practically in the same length of crankshaft travel instead of extending the period too long and creating too high a pressure at high speed by trying to pass the larger volume through the same opening. The area of injection into the cylinder increases gradually with the speed, and the pressure in the injection line is retained at from 6000 to 7000 lb. per sq. in.

NO COLD-WEATHER TROUBLE OR CARBON DEPOSIT

QUESTION:—What has been done to determine the possible difficulties with fuel oil at low temperatures, say 10 deg. below zero? Does the oil flow freely from the fuel tank, or must it be heated or put under pressure?

MR. ATTENDU:—The lowest temperature at which we have run the engine was about 0 deg. fahr., using 18 to 20-deg. Baumé fuel oil, which does not thicken materially before the temperature drops to —10 deg. fahr. Gas oil will not thicken until the temperature is about 40 or 50 deg. below zero fahr. The engine has been started in a temperature a few degrees below 0 deg. fahr. without any preliminary heating or any aids of that kind. In cold weather, this engine starts much more easily than any gasoline engine; it starts positively in two or three revolutions. This is the experience we have had in Montreal, running the car from May 25 to Dec. 3, 1924.

QUESTION:—How much carbon is deposited in the head compared with the deposition in a gasoline engine? What is the head-temperature range?

MR. ATTENDU:—I take for granted that by "head temperature" the cooling-water temperature is meant. The combustion temperature runs up to between 1500 and 1600 deg. fahr., as the maximum water-jacket temperature runs from 140 to 152 deg. fahr. As for carbon deposition, the head of our engine is perfectly clean whether the engine is taken down after 5 min. or 5 hr. of running.

QUESTION:—What percentage of the rated horsepower is required for starting; that is, the relative starting torque?

MR. ATTENDU:—No tests have yet been made on the starting of the aviation engine, as this is an experimental two-cylinder engine only and is connected to the dynamometer that takes care of the starting. The main test was on the four-cylinder engine, for which we used the standard 6-volt starter and this was all right when the engine was hot. The flywheel on the first four-cylinder engine was of the truck type which is about 4 in. larger in diameter than the standard-type automobile flywheel. Consequently, the 6-volt starter did not turn it fast enough to start the engine when cold and, therefore, still using the 6-volt starter, I put on a 12-volt battery that brought the speed up to between 110 and 120 r.p.m. and the engine started readily. About 1½ to 2 hp. is required to start this engine.

FUEL NOZZLE, COMPRESSION PRESSURE AND ECONOMY

QUESTION:—What type of fuel nozzle is used? What is the size of the hole in the nozzle? What is the compression?

MR. ATTENDU:—The nozzle orifice is merely a pinhole. In the small four-cylinder engine the hole is 0.015 in. in diameter and the lift of the valve-pin is 0.006 in. for the low-speed adjustment and 0.014 in. for the high-speed adjustment. In the aviation engine, the hole diameter is 0.020 in. and the lift is 0.004 in. for the low-speed ad-

justment and an additional 0.006 in. for the high-speed adjustment, making a total lift of 0.010 in. at high-speed.

The compression of air alone in the aviation engine ranges from 510 lb. per sq. in. at 400 r.p.m. to 530 lb. per sq. in. at 1600 r.p.m. with full retardation. As soon as fuel is injected, the ultimate pressure goes up as the time of injection varies and, at 1600 r.p.m., with a timer advance of 30 deg., the maximum pressure of the combustion charge is 752 lb. per sq. in.

QUESTION:—Have you made an analysis to determine why the fuel-consumption is 0.5 or 0.6 lb. per hp-hr. when the compression-ratio should give much better economy?

MR. ATTENDU:—It should be conceded that these engines represent a development. If you compare the results obtained from the first engine, which consumed 2 lb. of fuel per hp-hr., and from the second engine when it developed 18 b.hp. on a fuel-consumption of about 1.25 lb. per hp-hr.; and later when it developed 56 b.hp. on 0.76 lb. of fuel per hp-hr., I think you will admit that we made a gain with the aviation engine in reducing the consumption to 0.60 lb. per hp-hr. I expect to reduce this to 0.50 lb. per hp-hr. We still have some more work to do on the fuel injection, because some of that fuel oil is still lost, especially at high-speeds.

QUESTION:—What is the exhaust pressure at full engine-load?

MR. ATTENDU:—About 65 to 75 lb. per sq. in. at the beginning of the exhaust.

QUESTION:—How is the small injection-jet prevented from becoming stopped by dirt in the fuel? Do you use an oil-filter for the fuel oil?

MR. ATTENDU:—We buy 18 to 22-deg. Baumé fuel oil by the barrel, tap the barrel directly to an ordinary automobile-type strainer and from the strainer lead it directly inside the pump. We have no other means of filtering the oil than you have on your own automobile.

SCAVENGING PRESSURE AND VARIABLE INJECTION-TIME

QUESTION:—By what symptoms was it found that scavenging was imperfect?

MR. ATTENDU:—First, the exhaust was very smoky. Part of the smoke was dead black and the rest was white. The dead black was pure carbon and the white was partly burned oil that was not mixed at all with the air. We found that, at 34 lb. per sq. in. initial pressure of the air-compressor, the air, instead of entering the engine as a layer and pushing the dead gases ahead of it, really pierced the gases in the cylinder and, due to the very short period, the air was passing out at the same time that part of the dead gases were passing out; but most of the gases were retained inside the cylinder. To overcome this, we did not increase the capacity of the air-compressor but merely reduced the pressure of the transferred air. This pressure is now 14 lb. per sq. in. The same pressure is used in the aviation engine and seems to give good results.

QUESTION:—How do you explain the constant-pressure card at low speed and the constant-volume card at high speed?

MR. ATTENDU:—At low speed the time of injection of the oil is practically at top dead-center of the piston; that is, the beginning of injection is practically at top dead-center or a very little in advance of it. In the small four-cylinder engine, at 300 r.p.m., the time of injection is about 5 deg. before top dead-center at full retardation. In the aviation engine, the injection is timed to start at 7 deg. before top dead-center. Naturally, at idling position, a peak card is produced; but, at maximum load and low-speed, if the injection occurs during 20, 30 or 40 deg. of the stroke, injection begins from 5 to 7 deg. before top dead-center and continues after it, which produces a more or less flat diagram. At 1600 r.p.m., the maximum period of injection on this engine is during 51 deg. of the stroke and all the oil is injected before the piston reaches top dead-center; hence, the engine produces a peak indicator-card.

QUESTION:—Why are ball-bearings used on the crankshaft?

MR. ATTENDU:—The first engine was built with ball-bearings to reduce friction to the minimum; but plain bearings are used in the new designs, starting with the aviation engine. The only objection to ball-bearings for such types of engine is their high cost. Our experience with them shows that they stand-up excellently.

COMPRESSION RETENTION AND TEMPERATURE

QUESTION:—How long will the pressure of compression be maintained without re-boring the cylinder?

MR. ATTENDU:—In my estimation, the engine will retain its compression without re-boring as long as the gas engine will. The aviation engines have each been run about 200 hr. only, but the No. 1 small four-cylinder engine has been run more than 2000 hr., No. 2 for 1500 hr. and No. 3 actually has been run in the car for 1200 hr. They still retain their compression and the wear is not appreciable.

QUESTION:—What is the maximum compression-temperature?

MR. ATTENDU:—At full load, full throttle and full advance, it is about 1700 deg. fahr.

QUESTION:—Is the speed limited by the rate of flame propagation or gas-flow in the engines so far built?

MR. ATTENDU:—Up to October, 1925, the peak speed for all of these engines, using the 18 to 22-deg. Baumé fuel, appeared to be around 1400 r.p.m. I thought that perhaps the limitation was due to the density of the fuel and tried gas oil, but the results were exactly the same. Since October the peak is 1620 r.p.m., and shows a tendency to increase with the load. When tests have been made with the improvements that are now in course of making, I shall be in better position to answer this question, but I firmly believe that we have not yet reached the point at which flame propagation will stop us.

QUESTION:—How is the side-thrust on the valve, from the camshaft taken?

MR. ATTENDU:—It is taken only by the valve guides and the guides stand-up all right, but the acceleration of the inlet-valve was found to be too fast at high speed and caused the valve adjustments and tappets to break. A new camshaft has been designed in which the first 15 deg. of the cam will merely start the valve moving and this will also decrease the side-thrust to a large extent. With the old camshaft the point of contact is about 1/8 in. from the edge of the tappet; whereas, the point of contact with the new camshaft is 5/16 in. from the center of the tappet.

PRESENT AND EXPECTED MEAN-EFFECTIVE PRESSURE

QUESTION:—What is the mean-effective pressure on a horsepower basis? What are the diameter and the stroke of the fuel-pump?

MR. ATTENDU:—The actual brake mean-effective pressure in the aviation engine is 77.28 lb. per sq. in. for a continuous run of 3 hr. in which the engine developed 85 b.hp. It is expected, with the new changes, to bring the brake mean-effective pressure to about between 87 and 90 lb. per sq. in. with an output of 115 b.hp.

The diameter of the pressure-pump is 3/8 in. and the piston stroke is 5/8 in. The metering-pump has a bore of 1/4 in. and a stroke of 1/2 in., maximum.

QUESTION:—How does the fuel-consumption vary with the load? Does the fuel nozzle remain free from carbon?

MR. ATTENDU:—Fuel-consumption increases very slightly with reduction of load. Tests to date show that the variation is practically negligible. The fuel nozzle is always absolutely free from any carbon formation.

QUESTION:—What is the heat value, or thermal efficiency, of the fuel used?

MR. ATTENDU:—The 18 to 22-deg. Baumé fuel oil has a heat value of 19,260 B.t.u. per lb., and an actual thermal efficiency of 22.3 per cent.

QUESTION:—What is your estimate of the production cost of the engine per brake-horsepower?

MR. ATTENDU:—The cost of production will vary with the quantity produced and the type of engine. The only parts that differ from those of the present gasoline engine are the fuel pump and the injectors. These are intended to be built of standard size, and the only changes to be made for different sizes of engine would be in the bore and stroke of the pump and the diameter of the orifice for the injectors. I am now adapting the pump that was designed and used for a 3 1/2 x 5 1/2-in. four-cylinder engine to a 6 1/2 x 9-in. four-cylinder engine. The only change made is reboring the pump; the injection orifice is enlarged to 0.025 in. The elimination of carbureter, distributor or magneto, spark-plugs, and wiring should be taken into consideration in estimating the cost. The general workmanship on the engine does not need to be more accurate than for the ordinary gasoline engine; piston clearances are the same and piston-rings and bearing material are standard.

SEEK CRACKING PROCESS FOR PRODUCTION OF NON-DETONATING FUEL

BY J. B. HILL[2] AND T. G. DELBRIDGE[3]

ABSTRACT

EXTENSIVE investigation is being undertaken by the petroleum industry with a view to producing, by improved cracking processes, a sufficient supply of internal-combustion-engine fuels that will fire without detonation at compression pressures of about 150 lb. It has been shown conclusively that gasolines produced by the present cracking processes are appreciably better from a detonation standpoint than uncracked gasolines from the same crudes and should have a compression limit of about 85 or 90 lb. It is also known from fundamental research work and from practical experience with cracking processes that higher cracking-temperatures tend to produce a larger proportion of the naphthenic and aromatic compounds that show non-detonating tendencies, hence it should be possible to work-out cracking conditions under which the reaction could be controlled so that the maximum production of the higher-compression fuels would be obtained.

Causes that led to the present demand for the greater engine-efficiency that results from higher compression-pressures are reviewed by the authors and they point out that changes made in gasoline-production methods to increase the supply of automotive-engine fuel have raised the boiling-point and the molecular weight of the fuel. This heavier fuel has a marked tendency to detonate under high compression and under extreme conditions of open throttle and low speed. The main problem, therefore, is that of producing a sufficient supply of fuel that will not detonate at the desired compressions. Every motor fuel, so far as known, has a certain compression-limit, under any given set of conditions, beyond which it will detonate, but the fuels differ in this characteristic and may be classed according to this limit.

Benzol and alcohol have very high compression-limits but the present supply of them is utterly inadequate, even when mixed with large proportions of gasoline to produce a fuel that will not detonate in engines at present in use. Benzol production is increasing rapidly and may become an important factor in the situation. Of a total production of approximately 10,700,000,000 gal. of gasoline in 1925, it is estimated that 2,000,000,000 gal., or 19 per cent, was uncracked gasoline from California and Gulf Coast crudes and had a compression limit of 85 lb.; that 5,200,000,000 gal., or 48 per cent, was uncracked gasoline from other crudes and had a compression limit of about 70 lb., and that the remaining 3,500,000,000 gal., or 33 per cent, was cracked gasoline having a compression limit of 85 lb. Thus, 52 per cent of the total, if segregated, would be non-detonating at 85-lb. compression. By mixing the production of 90,000,000 gal. of benzol with 90 per cent of the 70-lb.-compression gasoline, an additional 8 per cent of 85-lb.-compression fuel could be obtained. If one-half of the 500,000,000 tons of soft coal mined annually were subjected to the low-temperature carbonization process, the production of benzol would be increased to 1,250,000,000 gal. per year, which would be available for blending.

The production of gasoline by cracking is increasing more rapidly than total production and in 1927 may equal the production of uncracked gasoline. The petroleum industry looks to improvements in cracking methods as a solution of the problem of an ample supply of fuel that will not detonate in engines having a reasonably high compression-ratio, but it should know what compression the engine builders desire to use so that it can make a suitable fuel generally available and yet conserve the supply of fuel having a higher compression-limit.—[Printed in the March, 1926, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN H. M. CRANE[4]:—A session on fuels and lubrication, or one on each, has become almost a semi-annual fixture in the Society's meetings. So far as I am concerned, it does not seem possible, even with these numerous sessions, to keep up with the rapid developments in fuel as they relate to its varying qualities and performance in engines, and in the various devices and improvements in engine design for making the best use of the fuel available.

My clear recollection, so far as the automotive industry is concerned, is that detonation, while a subject of discussion from time to time, became an acute problem among engineers only during and immediately after the war. Since that time it has been the subject of most intensive research by both the fuel and the automotive in-

[2] M.S.A.E.—Chief research chemist, Atlantic Refining Co., Philadelphia.

[3] Supervisor of the process division, Atlantic Refining Co., Philadelphia.

[4] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

dustry, with the result that some remarkable strides have been made in the control of detonation, both by mixtures of fuel and by engine design. Mixtures of fuel are not necessarily mixtures of gasoline and a separate material but, apparently, it is possible, by taking the products of petroleum distillation alone, to control detonation very considerably.

Car engineers have been faced for years with the serious problem of securing both power and economy in the use of fuel, which involves the compression pressure that can be used. So long as fuel varied greatly in detonation value in different parts of the Country, it was almost impossible to take advantage of a particularly good fuel in any particular part of the Country. With increased knowledge of the ability to control detonation and apparently a fairly wide-open field as to methods of control, it is to be hoped that a much more uniform type of fuel will be provided in all the filling stations, in which case the car builder can then push the engine compression up to the maximum useful limit and the public will derive advantage in greater fuel economy and better general car-performance.

The company with which the authors of the paper are connected is one of a considerable number that have cooperated in a most generous way with the Society in the advancement of knowledge regarding the varying properties of fuel. We are indebted to them for giving us at this time an official statement of the modification of a very important characteristic of motor fuel that is now under way.

Many Would Use a Special Fuel

One statement that Mr. Hill made indicated a possible deadlock; the oil companies are not likely to distribute a non-detonating fuel if the engines do not demand it, yet the engineers can hardly produce high-compression engines requiring non-detonating fuel until the distribution of such a fuel is nearly universal. Practically, however, the deadlock does not exist to that extent. Many cars have been produced in the last 10 years, as we all know, that have had compression-ratios that actually required for really satisfactory operation, a fuel of better detonation characteristics than the fuel that usually is supplied commercially. Engineers have developed cars that used a temporary local gasoline-supply of unusually good anti-detonating characteristics, and these cars, when shipped to other parts of the Country, have given trouble. Other engineers have been lured into giving the engine a higher compression-ratio than was satisfactory in other respects by the fact that an increase in compression-ratio noticeably increases the peak power at high engine-speeds. It not only increases the torque at a given high-speed, but tends to push the peak of the power curve up to a higher number of revolutions, and a very appreciable gain in maximum power is obtained thereby.

For these reasons, many cars are in use today in various parts of the Country whose owners are willing to pay a higher price for fuel of better anti-detonating characteristics than those possessed by the usual commercial supply. That fact resulted in large sales of tetra-ethyl lead, the use of a great part of the available benzol and making it worthwhile for the oil companies to advertise the anti-detonating value of the gasoline that they are ready to supply today. In addition to that, many operators of fleets of vehicles can control their source of supply and the design and upkeep of their powerplants within certain limitations, and railroad companies, when they begin to use rail-cars to a considerable extent, can do the same; hence, there are commercial applications in which fuel consideration can be based on definite facts, and therefore a general compromise does not have to be made.

I feel that we are progressing very fast along the line of increased efficiency and better use of our available fuel-supplies. Certain members of the Society think the engineers are not taking full advantage of the new possibilities in the control of detonation, but I think that the obvious tremendous advantage of increasing compression-ratios, which cannot fail to arise with every design of a new car and with every proposed change in an old car, is sure to result in keeping the compression-ratios of our engines up to the full limit and possibly in pushing the limit a little farther than we should go.

Greater Power Permits Increased Gear-Ratio

THOMAS MIDGLEY, JR.[5]:—The paper mentioned that there were certain commercial disadvantages in the use of aniline and tetra-ethyl lead. I think there are some commercial disadvantages in the use of aniline at present, at least, and I assume that the paper was written more than a week ago, before the last commercial limitation was lifted by the Surgeon General's committee on the sale of gasoline containing tetra-ethyl lead. A few restrictions are placed on the manufacture and mixing of the concentrated material, but this is simply in accordance with the general practice with regard to any commodity whose manufacture and handling are attended with danger.

I think the speaker did not emphasize the increases in efficiency that are obtained with higher compression. It is true that the curve he showed is approximated by efficiency at full torque, but if we install an engine in an automobile which has sufficient power to drive the car satisfactorily and then, by raising the compression and using a suitable fuel, we increase the efficiency, we at the same time increase the power output of any given torque by the amount of the increased efficiency; hence, we have an automobile that is greatly over-powered. The rear-axle ratio can then be changed to compensate for this increase in maximum power and a decided increase obtained throughout the normal driving-range in addition to the original increase. Roughly, the efficiency curve as shown for full torque is approximately one-half of that which will actually be obtained on the road. In other words, the increase in efficiency can be used twice, once directly and the second time, with more power available, by changing the axle ratio accordingly, which reduces friction losses in the engine.

CHAIRMAN CRANE:—Mr. Midgley's statement of the possible increases in efficiency by the ability to raise the compression-ratio will be admitted by most engineers as practically correct, I think. Of course, its application to present cars depends partly upon how far we have already gone. Certain cars today require a treated fuel to give really satisfactory results in a sea-level territory and where hill climbing constitutes the greater part of the work that the car does.

The sort of fuel described by Mr. Hill seems to the car engineer almost too good to be true. Ten years ago we were fighting to hold our own on compression-ratio with the fuel one could buy at the filling stations, and now we are invited not only to see how good the fuel is but to demand higher compression-ratios and the fuel to suit them.

W. G. WALL[6]:—I have always thought that most of our

[5] M.S.A.E.—Second vice-president and general manager, Ethyl Gasoline Corporation, New York City.

[6] M.S.A.E.—Consulting engineer, Indianapolis.

troubles with gasoline engines were due to the fuel used in them. When we buy most commodities, such as metals, we get an article of known definite properties but, when we buy gasoline, we never get the same ratio of different compounds.

If we attempt to use high-compression engines and depend upon getting good results by the simple expedient of using higher-gravity hydrocarbons, we run into a number of difficulties. We probably do not have detonation but we do not get flexibility and the engine is difficult to start unless some special method of starting is used. At the same time, it will be a fine thing for the engineer, when designing his engines, to know that the users will be able to get an exact fuel-mixture, whatever it is ultimately to be. It is very indefinite at present, and engineers have been and are expected to design engines that will function equally well with fuels of various mixtures. It does not seem that it would be very difficult to provide gasoline having exact quantities of each of the hydrocarbons. If we had had a mixture of two or three of the more suitable hydrocarbons, we could have produced engines by this time that probably would have been remarkably efficient.

CHAIRMAN CRANE:—The oil companies are drawing out of the ground a mixture over which they have no control. They may know when they put a well down in a certain field that something like a certain type of crude will come out of it but, when they tap a new field, they are more or less in the position of having to dispose in a reasonable length of time of what they get out of the ground. Crude oil is very expensive to store in the quantities required by the automotive industry and the production processes are none too accurate.

J. B. HILL:—It would be difficult to produce a consistent gasoline from the various compounds and I do not think it is necessary. Gasoline, as it is produced today, is a mixture of a vast number of compounds; I think it contains 1000, at a conservative estimate. It naturally would be impossible to isolate each of those and then blend them in the right proportions. The petroleum industry is, however, working toward something that will give the same result, I believe, and that is to produce a mixture of a certain standard volatility. Many companies are now producing a fairly standard product.

QUESTION:—Do the Western gasoline and the cracked gasoline have desirable volatility characteristics in addition to anti-knock qualities?

MR. HILL:—The over-point has dropped in recent years, due partly to the production of cracked gasoline, which tends to produce a more volatile motor-fuel. The Western gasolines, of course, vary among themselves.

NON-DETONATING MOTOR FUEL FROM HEAVY OIL

R. H. SHERRY[7]:—Compressions "of the order of 90 lb." may be said to be commonplace. What is wanted is compression of the order of from 125 to 150 lb. per sq. in. Fuels that will permit such compression without detonation are in use, but their universal use is prevented by lack of sufficient quantity and by the price that must be paid for them.

In the discussion of T. A. Boyd's paper on Fuel from the Service Standpoint at the Service Meeting in Chicago in November, 1925, it was stated that a non-detonating fuel made by a "vapor-phase" process had been placed on the market[8], but the conclusion was drawn that dependence must be placed on California fuels. It is to be hoped that this "vapor-phase" fuel will some day receive

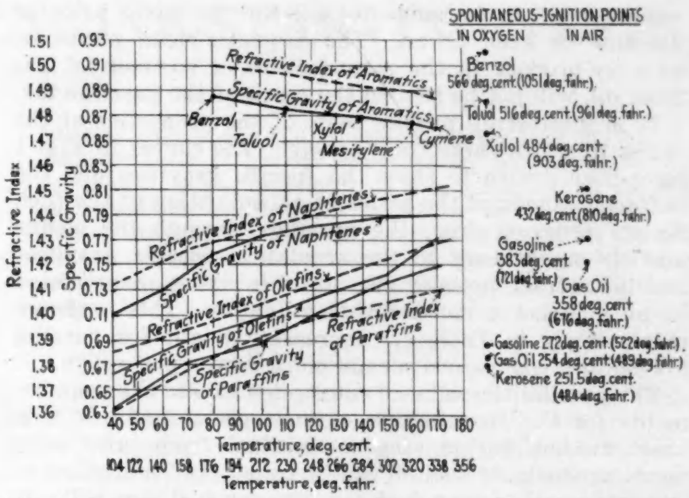

FIG. 1—SPECIFIC GRAVITIES AND THE REFRACTIVE INDEX OF A SERIES OF FUELS

As Progress Is Made from the Paraffins through the Olefins and the Naphthenes to the Aromatics, Specific Gravities and the Refractive Index Rise, This Rise Being Accompanied by an Increase in Non-Detonating Quality as Is Brought Out in Table 1

the technical discussion that it deserves. The present discussion is offered more from the practical viewpoint.

Much attention was given at one time to cyclohexane and benzol as bases for non-detonating fuels, as these fuels are practically non-detonating. The former is scarce and the latter comparatively scarce and somewhat costly. As benzol freezes at 41 deg. fahr., its use in cold weather is out of the question. On the other hand, large quantities of fuels belonging to another organic series, such as the paraffins, are available. The problem has been whether paraffin can be converted into the more desirable series. This problem has been solved recently, not experimentally, but commercially. The paraffins, C_nH_{2n+2} when passed over red-hot metallic oxides, such as iron oxide, can be converted into members of two other series, the olefins, C_nH_{2n}, and the aromatics, C_nH_{2n-6}. Through some recent developments, a strong possibility exists that a similar process can be used for the manufacture of commercial gas, yielding as a by-product a combination of aromatics and olefins that, when blended with gasoline, will make a very satisfactory fuel for high-compression engines, a fuel with a freezing point below—15 deg. fahr.

This process for changing the organic series of oils and heavy oils into motor fuel, not to mention other possibilities, embodies a new principle at least. The

TABLE 1—RELATIONSHIPS OF THE SPECIFIC GRAVITY, THE REFRACTIVE INDEX AND THE SPONTANEOUS IGNITION POINTS TO THE COMPRESSION OF MOTOR FUELS[9]

Fuel	Specific Gravity	Refractive Index	Compression Pressures without Detonation, Lb. per Sq. In.
Paraffins	0.632 to 0.750	1.360 to 1.410	90
Olefins	0.664 to 0.772	1.385 to 1.450	110
Naphthenes	0.710 to 0.790	1.412 to 1.452	180
Aromatics:			
Benzol	0.886	1.500	Practically Non-Detonating
Toluol	0.875	1.497	
Xylol	0.870	1.492	

[9] Illustrating the rule that the heavier the specific gravity and the higher the refractive index are, the greater will be the compression pressure that can be used without detonation. The position of the spontaneous-ignition points of the different fuels, shown in Fig. 1, offers an explanation of the difference in the non-detonating quality of the various series of hydrocarbons.

[7] M.S.A.E.—Consulting engineer, Evanston, Ill.

[8] See THE JOURNAL, June, 1926, p. 647.

naphthenes can be made to sell for the same price as gasoline or even lower. The aromatic-olefin mixtures, as a by-product in the manufacture of commercial gas from oil, will not be beyond the reach of the gasoline tax.

It is interesting to note some of the properties of the series to which these fuels belong. The curves in Fig. 1 have been drawn to show the specific gravities and the refractive index of the series as an indication of the fuel. As we progress from the paraffins through the olefins and the naphthenes to the aromatics, specific gravities and the refractive index rise and this rise is accompanied by an increase in non-detonating quality. This is shown more simply in Table 1. Increased weight for parallel low-boiling compounds means more power per gallon.

The possibilities in such conversion exceed the requirements for the manufacture of any special fuel. It is a basic method for making motor fuel from practically waste products, if fuel oil can be called that, and of making, not merely motor fuel, but a motor fuel that will not detonate under the higher compressions that are demanded. The results that have been obtained are worthy of the serious attention and cooperation of the automotive engineers and the oil industry. If nascent hydrogen is introduced into the vapors, another series, the naphthenes, or cyclo compounds, C_nH_{2n}, will be formed. Not only does this change of series occur, but the high-boiling compounds will be broken-down into low-boiling compounds. Thus, heavy oils, of use only for fuel, can be converted easily into motor fuel. It is by this method that the "vapor-phase" fuel is made.

Conversion at Atmospheric Pressure Produces Naphthene

"Vapor-phase" is a technical term that has an interesting meaning. In the present cracking processes, high pressures and temperatures are required. "Vapor-phase" means that conversion is by simple distillation and requires only atmospheric pressure. The process is not cracking, however similar they may appear, but a chemical conversion by oxidation of the hydrogen, taking it away to form other compounds and water, or subsequently returning some to produce still other results.

When completely converted, this fuel consists entirely of naphthenes; but, for commercial purposes, to avoid changing carbureter adjustments, it is blended with gasoline in the customary proportion of 60 per cent of gasoline to 40 per cent of cyclo compounds, which produces a mixture that is non-detonating with compression pressures higher than 125 lb. per sq. in. The straight naphthene fuel is non-detonating with compression pressures of 160 lb. per sq. in. Tested in a Packard engine, this fuel was found equivalent to a 60-per cent benzol-mixture, as it showed no detonation with a compression pressure of 160 lb. per sq. in. This result was checked in a test by the Navy, in which test no detonation occurred at 160-lb per sq. in. compression-pressure. One California oil company that owns a well delivering oil that contains as much as 40 per cent of naphthenes, investigated this and found no detonation with a compression pressure of 140 lb. per sq. in.

If the aromatic series can be produced at a reasonable price, blends can be made that will have a compression value possibly even higher than the naphthenes.

Differentiation of Fuels by Colors

QUESTION:—Would it not be possible for the oil companies to color gasolines of certain characteristics in different ways so that the public could distinguish them?

MR. HILL:—Many fuels are being colored today. Some colors mean something and others do not. It would be necessary for definite standards to be placed on gasolines of different colors and the product would need checking-up under a law similar to the pure-food laws.

QUESTION:—Does not the material used for coloring have some effect upon the fuel?

MR. HILL:—The quantity of material used for coloring is so small that it seems to me the only effect it could have on the fuel would be to deposit in very minute quantities on the intake system. I think, however, there is not much danger of that. There will be enough liquid going through the intake system to carry that minute quantity of coloring matter along.

QUESTION:—Can the refiner control the stability of the cracked fuel to permit long storage?

MR. HILL:—That is something toward which we are working. The more highly cracked fuels, such as Mr. Sherry described, have not been found very stable in our present experience on storage. Refiners are working toward a cracking process that will give a large percentage of naphthenes, for example, which are entirely stable in storage. We are hoping, by controlling both temperature and pressure, that such a type of fuel can be produced satisfactorily.

Uniform Operating-Temperatures Desirable

W. S. JAMES[10]:—Mr. Wall stated that gasolines are of widely varying compositions and that the automotive engineer cannot build his engines to use all the different kinds of gasoline. Assume, on the other hand, that you are producing a gasoline; are all automotive engines the same? One gasoline cannot be made for Packards and another for Fords. The same gasoline must be used in both, therefore, the problem is not altogether that of the oil refiner, but it is equally that of the automotive engineer. If automotive engines were as uniform in their operating temperatures as the gasolines at present available are in their volatility, it would be no great problem to fit fuels to engines or engines to fuels. I think Mr. Wall's question should be considered seriously from the point of view of making the temperature conditions in automotive engines uniform.

[10] M.S.A.E.—Assistant technologist, Associated Oil Co., San Francisco.

PROGRESS REPORT ON ENGINE-STARTING TESTS

BY JOHN O. EISINGER[11]

ABSTRACT

THIS report supplements previous progress reports on the Cooperative Fuel Research and brings uptodate the information on engine-starting tests that were made in the last year. Tests made with two types of standard carbureter show that the laboratory test-apparatus gave similar results as regards time required for starting the engine and that throttling with the test set-up produced similar results as throttling with one of the carbureters. For subsequent starting-tests with the test set-up, the former cranking speed was reduced from 200 to 100 r.p.m.

Tests were made at different air-temperatures with three fuels having different distillation-characteristics as designated by the Steering Committee, which had stressed the importance of obtaining information as to the magnitude and nature of the changes in fuel that would be necessary to make starting as easy in cold weather as in warm. Comparisons between two fuels having rather widely different distillation-characteristics were made at air-inlet temperatures of 68 and 36 deg. fahr. and indicate wide differences in starting time at the lower temperature. As different amounts of the two fuels are required to start the engine in a given time, it is indicated that different amounts are vaporized, which is supported by the distillation curves that show proportionately wider differences in distillation as the temperature is reduced.

Starting performances of another pair of fuels were closely similar at an air temperature of 81 deg. fahr. but at 25 deg. fahr. one failed to start the engine while the other started it in from 10 to 29 sec. at different rates of fuel-flow. A third pair of fuels that had the same distillation-characteristics up to 10 per cent of the fuel, gave approximately the same starting performance at 43 deg. fahr., hence it seems probable that less than 10 per cent is vaporized under these conditions, but at an air temperature of 68 deg. fahr. differences in starting performance which indicate that considerably more than 10 per cent is vaporized are found.

Comparison of a fourth pair of fuels, one of which was a 50-per cent benzol blend, shows that the latter gives quicker starting than the other at a lower rate of fuel flow at an air temperature of 66 deg. fahr., whereas at 30 deg. the benzol blend requires a longer starting time with a high rate of flow and less time with a low rate of flow. Thus, the same amount of the two fuels is needed to start the engine in 7 sec., but more benzol blend is needed to start it in 4 sec. and less to start it in 10 sec.

The tests indicate that within certain limits richness of the fuel determines the number of revolutions the engine must make before an explosion is obtained. Richness of the mixture in the cylinder rather than that of the mixture leaving the carbureter determines whether or not an explosion will occur, and this is believed to be a function of delayed vaporization of fuel left in liquid form in the manifold and cylinder during previous cycles.

If the fuel characteristics could be changed gradually as cold weather approaches, somewhat as the distillation curves and the starting performances of the different fuels at various temperatures indicate to be desirable, it might be possible to obtain very nearly the same starting performance in winter as in summer. One of the purposes of the research is to determine the general nature and magnitude of the changes that might accomplish this result.—[Printed in the February, 1926, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN F. O. CLEMENTS[12]:—The Society is doing considerable cooperative research-work. We are cooperating with other National Societies and with the Bureau of Standards. This correlated and coordinated work is necessary on a number of subjects; the fuel problem is one of them. The Society is spending about 12 per cent of its income on the work of the Research Committee. Research is proceeding on six or seven different projects, and the results therefrom are available for the entire industry.

Our laboratory has been doing some work on the starting characteristics of fuels, utilizing a bomb as our means of gathering data, and finds that the data check within about 1 per cent, time after time. We are plotting the fuel-air ratio against temperature and getting very well coordinated results. We hope that we can borrow some of the Bureau's fuels and test them by this particular method, to determine the agreement of methods. I have tried to pick flaws in this particular work; but, thus far, I have not been able to do so.

F. C. MOCK[13]:—As a carbureter man, I have been thinking what a fine alibi a general knowledge of the facts demonstrated by Mr. Eisinger would afford for my product. In fact, this is the reason that carburetion is one of the major problems of automotive engineering. For instance, Mr. Eisinger's demonstration shows that it is necessary to use for starting at least four times the mixture strength that is required after an engine has been operated a few minutes; and it may, in cold weather, require ½ hr. or longer of driving before temperature conditions in an intake system reach a point at which the engine will operate on a normal economical mixture. Further, for driving with partly open throttle, a lower vapor-density is needed than at full-open throttle, and this lower vapor-density for part-throttle operation can be obtained with a cooler engine, or more quickly after starting, than with the wide-open throttle heavier vapor-density. Therefore, if the carbureter has the correct mixture-range when the engine is warm, its delivery will be unsatisfactory, when the engine is cold, by a percentage varying with the load and the manifold air-velocity; and the amount of this variation depends not only on the temperature but upon the volatility of the fuel. It is no wonder that a carbureter set for Detroit conditions is unsatisfactory in California.

A man told me recently that the idea of having carbureter adjustments is all wrong. He said that a carbureter should go out sealed-up like a camera, and that no necessity should arise for the service man, the customer or a mechanic to change the carbureter, whether it be used in summer or in winter. I think this is plainly impossible.

J. H. HUNT[14]:—The engine-starting tests[15] reported on by Mr. Eisinger at the 1925 Semi-Annual Meeting were somewhat along this same line but were made with higher

[11] Jun. S.A.E.—Automobile powerplant section, Bureau of Standards, City of Washington.

[12] M.S.A.E.—Technical director, General Motors Corporation Research Laboratories, Detroit.

[13] M.S.A.E.—Research engineer, Stromberg Motor Devices Co., Chicago.

[14] M.S.A.E.—Head of electrical division, General Motors Corporation Research Laboratories, Detroit.

[15] See THE JOURNAL, July, 1925, p. 52.

cranking-speeds. Are the curves exactly similar for 200 and for 100 r.p.m., or do you find a difference?

J. O. EISINGER:—Concerning speed, no difference in the general results obtained was found. We had considerable difficulty at first in securing consistent results at 100 r.p.m., primarily on account of ignition but, with proper ignition, the general character of the curves at 200 r.p.m. is similar to those obtained at 100 r.p.m.

W. R. STRICKLAND[16]:—We are more concerned with 25 or 50 r.p.m. than with 100 r.p.m. We are also more concerned about starting at 0 deg. fahr or at 10 to 20 deg. below zero than at the temperatures shown in the charts.

Tests To Be Made at Different Temperatures

MR. EISINGER:—In that connection, we intend to outline a general method of testing gasoline for starting in which we shall select three temperatures; one below freezing, one about 32 deg. fahr. and one at room temperature, that is, approximately 70 deg. fahr.

CHAIRMAN CLEMENTS:—Cannot those temperatures be correlated now?

MR. EISINGER:—The lowest temperature we have obtained is about —10 deg. cent. (14 deg. fahr.).

E. S. MARKS[17]:—We have made a number of investigations to determine the effect of cranking speed on starting, holding the temperature constant at say 0 deg fahr. The results have checked very well with the Bureau's work insofar as speeds of 200 and 100 r.p.m. are concerned, but, when we reduced the speed to about 40 r.p.m., we also had difficulty in obtaining consistent results.

QUESTION:—Did any particular cylinder in the engine fire first in the Bureau's tests?

MR. EISINGER:—We made tests to determine that; namely, to find out whether there was any difference in distribution of the mixture in the engine. My paper on Engine-Starting Tests[18] includes a report of that test. We took the spark-plug leads off of three of the four cylinders and fired one cylinder at a time, alone. This was done for each cylinder, and the starting time was found to be the same. This showed that the distribution to all cylinders was more or less equal.

Fuel in Tank and Carbureter May Vary

C. F. TAYLOR[19]:—It occurs to me that, under starting conditions, the gasoline in the carbureter may be very different from that in the fuel tank. When a car is stopped with the engine hot, some of the lighter fractions of the fuel in both carbureter and vacuum tank are boiled-off. That the fuel used in starting is often less volatile than the sample on which the volatility test is made is, therefore, probable. It seems that a determination of the average difference between the gasoline used to fill the tank and that actually used in starting is of importance in connection with this work. Is any quantitative information available on this point?

H. E. PENGILLY[20]:—If those who have had trouble in starting on a cold morning will drain a little of the gasoline out of the carbureter, they will find that the gasoline in the vacuum tank is superior to that in the carbureter. The heat does drive off the light fractions.

[16] M.S.A.E.—Assistant chief engineer, Cadillac Motor Car Co., Detroit.

[17] M.S.A.E.—Chief engineer, H. H. Franklin Mfg. Co., Syracuse, N. Y.

[18] See THE JOURNAL, July, 1925, p. 52.

[19] M.S.A.E.—Associate professor of research in aeronautical automotive powerplants, Massachusetts Institute of Technology, Cambridge, Mass.

[20] M.S.A.E.—Automotive engineer, Standard Oil Co. of New York, New York City.

[21] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

MR. HUNT:—Was any liquid in the cylinder at the time of starting in the tests?

MR. EISINGER:—The time required to start the engine was taken from the time the fuel was turned-on until an explosion was heard. In every case, the quantity of liquid fuel in the manifold and cylinders prior to turning-on the fuel was insignificant.

MR. HUNT:—Did Mr. Marks make his tests with a commercial carbureter, the characteristics of which at 40 r.p.m. might have been a factor, or did he use a set-up somewhat like Mr. Eisinger's, in which the rate of fuel-flow was known accurately?

MR. MARKS:—We used a commercial carbureter. The rate of flow was not known accurately. The tests were made with just such a combination of engine and carbureter as we would sell to the public, in an effort to determine the relation between the number of revolutions per minute and the starting ability of the engine at a given known uniform temperature of 0 deg. fahr.

MR. EISINGER:—In some of our future work we intend to make tests at different cranking speeds to determine the effect of engine-speed upon starting.

Objects of Previous and Present Tests

H. M. CRANE[21]:—As a member of the Joint Fuel Committee, I think it would be well to explain a little more definitely the object of this set of tests. The Committee started about 4 years ago to endeavor to derive more good motor fuel from a barrel of crude oil. That involved the running of tests almost entirely with the object of determining how heavy a fuel can be used successfully without reducing the mileage per gallon to a point that will offset the gain in fuel available from a certain quantity of crude oil.

Those tests gave some very interesting results but obviously did not meet all the conditions, because, before a car can run it must start. Later, a research program was laid out that involved the starting possibilities. This is an interesting illustration of the way research goes. The start of the work must be made with only a general program, as in this case. Then the program must be developed as the work proceeds, and the apparatus must be developed to carry on the work.

The three fuel-curves presented by Mr. Eisinger show very clearly the bearing that this work has on the available quantity of fuel for use in cold weather, the interesting point being that the cold-weather start is based on the lower end of the volatility curve and not on the average volatility over the whole range. This test indicates plainly that, at a certain low temperature, the engine starts more easily with ordinary gasoline than with a benzol blend, although the volatility of the benzol is considerably better than that of the gasoline.

None of these tests are development tests to show particularly how to make cars easier to start, except so far as they will allow the oil companies to blend their fuel to better advantage for use in cold climates. In that respect the result of these tests unquestionably will increase our potential fuel supply for cold-weather use 10 or 15 per cent over the quantity we have known in the past.

Obviously, the desirable thing, if the kind of fuel wanted is known, is to develop some means of determining easily whether any particular fuel supplied is that or some other type. The fact that is hardest to determine, so far, and I think no one has yet found an easy method of doing it, is the average volatility of a given gasoline. What T. S. Sligh, Jr., is working out at the Bureau of Standards is a simple system for determining the start-

ing ability of a fuel, based on what the Bureau of Standards' work indicates is necessary for starting at different temperatures. To that extent, it is a very interesting piece of work and looks far more encouraging as to practical usefulness than the attempts that have been made on a general over-all test of the value of any given fuel.

I think there is not the slightest question as to the value of the work done by the Bureau of Standards for the Steering Committee. The members of the automotive industry have obtained a much better insight into the possibilities, while the engineers of the oil companies are much more informed about the characteristics of the conventional type of gasoline engine. This distribution of knowledge from one end of the industry to the other unquestionably has added to our available source of fuel up to 20 per cent and has helped to maintain the cost of fuel at a fairly satisfactory level.

T. S. SLIGH, JR.[22]:—I believe that either the bomb vapor or the flow method will give a very definite idea as to the starting value of the fuel and, in addition, that with the latter one can get with extreme ease a test for the effective volatility of the completely vaporized fuel or that of the 85 or 90-per cent vaporized fuel. I think that was what Mr. Crane had reference to when he said "average volatility." We expect to obtain both results with the flow method.

HIGH AVERAGE OPERATING-TEMPERATURE AND ENGINE AND CAR OPERATION

BY ALEX TAUB[23] AND L. P. SAUNDERS[24]

ABSTRACT

THIS subject is treated in a paper in two parts. Part I, by Alex Taub, deals with laboratory tests to prove by comparative data that the higher average operating-temperatures maintained in the engine by the constant-temperature, or evaporation, system of cooling have negligible detrimental effects. Part II, by L. P. Saunders, gives the results of road-tests of cars operated under the same conditions when fitted with a standard water-cooling radiator-core and with a constant-temperature cross-flow condenser-core.

Although contamination of the crankcase oil by heavy ends of the fuel is not prevented by the higher temperature of constant-temperature operation, it is asserted that this higher temperature is effective in striking an acceptable balance in such contamination and results of the tests show that the cylinder-walls are maintained at temperatures sufficiently above the vaporization point of water to reduce the condensation of water vapor to the minimum. Water in the crankcase is the objectionable element. Oil dilution by fuel up to a certain amount is not detrimental; in fact, experience shows that about 16 per cent of such dilution is necessary to facilitate starting a cold engine. Even when an antifreeze solution containing 50 per cent of alcohol is used and the boiling temperature reduced to 184 deg. fahr., the cylinder-wall temperatures are maintained at 212 deg. or more.

Since a boiling liquid does not change its temperature, it affords the simplest means of maintaining a constant operating-temperature and also the simplest, least expensive and lightest means of providing for quick warming-up of the engine and slow cooling-down, because there is no circulation of water except when steam is passing from the engine-block to the radiator or condenser.

Test runs were made in the laboratory with an engine fitted with a Muir constant-temperature system which could be converted to water-cooling by blocking-off the circulation through the cylinder-head with a special gasket to provide for concentrated circulation around the exhaust-valves. Outlet-water temperatures were controlled by admitting more or less cold water. Results of the tests indicate that fuel consumption is approximately the same for constant-temperature cooling at 212-deg. outlet temperature and water-cooling at 170-deg. outlet temperature; that with both systems the spark-lever advance for maximum torque is safely below the degrees of advance before detonation, or spark knock, begins; that the falling-off in torque with reduction in richness of the fuel mixture is virtually parallel for the two systems; that the difference in volumetric efficiency of the engine when operated on the two systems amounts to only 2 per cent, which is within the allowable error of the air-meter used; that the brake engine-pull is nearly identical; that the temperature of the lubricating oil is not affected by the system of cooling but by the temperature of the cooling medium, and that the temperature of the walls and inlet and exhaust-valve seats of the No. 1 and No. 6 cylinders of a six-cylinder engine is much more uniform with constant-temperature cooling than with water-cooling.

Cylinder-head formation and spark-plug location are important factors as regards detonation. A compact head with spark-plug carefully located to allow the maximum spark-advance before detonation starts provides sufficient leeway for the use of higher operating-temperatures.

With constant-temperature cooling it is advisable that the normal water-level be such that, in operation, the water flowing from the radiator to the engine-block will fill the pipe only about half full and allow air to escape above it, thereby eliminating the possibility of an air-trap in the water-pump.

A steam-dome capacity equal to 21 per cent of the normal quantity of water in the engine-block gives the proper proportion of water and steam passing to the radiator. The smallest possible quantity of water is the proper quantity to use, as the quantity of water in the block controls the warming-up period. The normal water-level is raised between 12 and 15 per cent by expansion and volcanic action of the water when the engine is running, and the capacity of the steam dome is thereby reduced 6 or 9 per cent. If the steam dome is too small, excess water will pass to the radiator.

That the high operating-temperatures that develop with constant-temperature cooling are safe is indicated by the much higher operating-temperatures in air-cooled engines.

In Part II, after pointing out the general recognition of over-cooling by the water cooling-system in winter, as made evident by the use of air shields on the radiators, and describing the operation of the Muir cross-flow condenser-core, the author gives the results of many road-tests of cars with water-cooling and constant-temperature cooling. It is shown that the cross-

[22] M.S.A.E.—Physicist, Bureau of Standards, City of Washington.

[23] M.S.A.E.—Development engineer, General Motors Corporation, Detroit.

[24] M.S.A.E.—Experimental engineer, Harrison Radiator Corporation, Detroit.

flow core, when used as a water-cooler, maintains a lower temperature of the outlet water from the radiator than the conventional core and still lower temperatures when used as a constant-temperature system.

Miles per gallon of fuel consumed are increased by constant-temperature cooling with the cross-flow core as compared with water-cooling with the standard core. Acceleration tests showed a slight advantage for the former system, while deceleration times were slightly longer than with water-cooling. The constant-temperature system showed higher speeds in hill-climbing.

Better ventilation of the engine hood may be necessary with the constant-temperature system to avoid uncomfortable heat in the driving portion of the car body. Size of the radiator-core cannot be decreased, as many cars are now inadequately cooled under certain extreme conditions of driving and air temperature and density. The fan size should remain as large, at least, as at present.

The paper is concluded with a chart showing the effects of temperatures in the water-jacket and in the lower part of the radiator caused by starting and stopping of the car in cold weather.—[Printed in the March, 1926, issue of THE JOURNAL.]

THE DISCUSSION

L. P. SAUNDERS:—I wish to point out the great difference in the fuel-consumption of the engine with a water-jacketed manifold at 10 m.p.h.—it was 10.6 miles per gal. with water-cooling and 18.1 miles per gal. with constant-temperature cooling—and that we obtained entirely different results due to poor distribution. With the other engine, on account of the heat in the manifold, we did not get that great difference in fuel-consumption between water-cooling and constant-temperature cooling.

FRED J. BEDFORD:—Was any adjustment made on the carbureter?

MR. SAUNDERS:—The carbureter setting was determined by obtaining the maximum acceleration from 5 to 25 m.p.h.

F. M. YOUNG:—What is the comparative cost of the cooling-system; for instance, on a large high-powered car originally designed with a narrow radiator?

What would be the temperature of the water in the jacket in zero weather?

Also, what are the permissible variations of water-level, and what are the differences between too high and too low a water-level?

MR. SAUNDERS:—If a car has an unusual radiator we cannot fit the cross-flow radiator, but the narrower and higher the radiator is the better it will be for the cross-flow. Such a radiator would have the same effect as a very wide and short radiator. We had considerable trouble with the radiator of the water-cooled system to get the water up high. At present, the cost is slightly greater than for a radiator of the down-flow-water type.

The temperature of the water in the block, with the system having the pump set-up high, will vary from 170 to 190 deg. fahr.; with the pump placed low so that the water can drain into it, the water temperature will be from 205 to 212 deg. fahr.

If the system is filled-up so that the radiator operates as in a water-cooled system and is then stressed so that the water boils, sufficient water will be forced out to make it into a condenser system; that is, if there is too much water. If there is insufficient water, it will operate exactly the same as a water-cooled system that has insufficient water.

QUESTION:—Does any difference exist between the ping in the water-cooled and that in the vapor-cooled engine? What effect does the combustion have on it?

PINGING DEPENDS UPON PARTICULAR ENGINE

MR. SAUNDERS:—The ping is a characteristic of the particular engine upon which the system is fitted. With an engine that does not ping badly, the same condition exists with the vapor-cooled system as with the water-cooled system, with the water at the same temperature. The worst condition obtainable with the constant-temperature system is when the water is at 212 deg. fahr. in summer. If the compression pressure, the carbureter setting and all other conditions are unchanged, no worse condition for pinging will be found at any time in the year.

CHAIRMAN H. L. HORNING[25]:—We do not fully know yet how to design either a water or a steam cooling-system. We know that with four engines of the same model, two gave less pinging at high temperatures with steam cooling-systems than they did with water cooling-systems, and that the other two, of slightly different design, detonated worse, due to the method of feeding the water.

H. A. HUEBOTTER:—Were any oil-dilution data obtained in the tests?

MR. SAUNDERS:—No.

ACCURACY OF METAL TEMPERATURES ASSURED

C. B. DICKSEE[26]:—What is the method of securing the thermocouple to the cylinder walls? To get a considerable error in temperature reading is very easy. Frequently, thermocouples are assumed to give an accurate temperature-reading no matter how they are attached to the surface. With small wires, the quantity of heat conducted away will produce a low temperature-reading and, with a high rate of heat conduction, this may result in an error of from 20 to 25 per cent. In such case almost any reading can be obtained with a thermocouple.

ALEXANDER TAUB:—We were very careful about inserting the thermocouples into the spots where we were taking readings and we insulated every portion within 6 in. of the spot carefully so that no external conditions could affect it. We are certain that the temperatures obtained were the actual temperatures of the spots chosen.

MR. DICKSEE:—What insulation method was used?

MR. TAUB:—The wires and the parts affected were wrapped carefully with both tape and asbestos.

HIGH TEMPERATURE REQUIRES SUITABLE OIL

W. W. WELLS:—About 10 years ago I suggested a constant-temperature cooling-system to the builder of the engines we were using. He replied that it would necessitate a particularly efficient oiling-system and bearings of a special design. Is it necessary to change the grade of oil or the oiling system?

MR. TAUB:—The cooling system makes no difference so far as the bearings are concerned. The power is not increased; therefore, the duty of the bearings is not increased. Concerning the oil, we have shown that the oil temperature goes up with the temperature of the cooling medium; therefore, an oil should be used which will operate satisfactorily at those temperatures.

CHAIRMAN HORNING:—In one application we purposely designed the engine for a high oil-temperature, following the Research Committee's investigation of the influence on dilution of oil temperatures up to 180 deg. fahr. A high temperature is all right on some engines but, on others, it would be ruinous. That engine, with

[25] M.S.A.E.—President and general manager, Waukesha Motor Co., Waukesha, Wis.

[26] M.S.A.E.—Section engineer, light and powerplant department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

steam-cooling, at 1800 r.p.m. and full load, with continuous running, gave no trouble with the bearings.

QUESTION:—Is it not true that each set of test figures given applies to a specific case and that we must not generalize too much, but that, if we intend to apply steam-cooling to any specific engine, that engine must be tried-out first to see whether the water passages are designed so as to permit free escape of the steam?

STEAM POCKETS MUST BE AVOIDED

MR. TAUB:—That is necessary. We cannot generalize on water-cooled engines; no two are alike. If a given water-cooled engine is to be converted into a steam-cooled engine, the water holes between the cylinder-block and the cylinder-head should certainly be calibrated to get the best condition. Every engine would be different; in fact, blocks for the same engine-model from different foundries would be different.

CHAIRMAN HORNING:—An engine that would pass the Society's inspection-test for good design for water-cooling never will give any trouble with steam-cooling. It is necessary to look out for steam pockets; but, from experience, I dare say that the steam cooling-system will operate satisfactorily with more steam pockets than the water cooling-system will. Steam is the cause of water-cooling being so troublesome. Steam disorganizes a water cooling-system; so, with a water cooling-system, steaming on a hill causes the average driver to associate trouble with steam. I think that belief is most difficult to overcome. The fact is that the water cooling-system is not particularly organized for steaming and the steam upsets it. If the steam is permitted an easy escape, no trouble will be experienced.

JACKET PASSAGES TOO SMALL IN SOME ENGINES

A MEMBER:—I believe that steam-cooling is right in principle but, from the way the data were presented, it seemed to me that there might be a misunderstanding. Engines exist in which the water must have velocity to cool certain spots. Some of them are designed with that in view and, if these figures were taken too generally, some tests might be made that would throw discredit on a system that is all right.

MR. TAUB:—That is true. I noticed some new cars at the automobile show which had some of the vital spots constructed so that water could not be got into them. We could no hope to steam-cool such an engine because the part to be cooled cannot be reached by the cooling medium.

JOHN S. ERSKINE:—Has any attempt been made deliberately to provide increased space in the cylinder-head to permit more violent agitation of the water? Is not that violent agitation around the top of the cylinder-head needed so that all the spots in the entire system will be cooled?

MR. SAUNDERS:—We have been working along those lines and believe we have found a method that will take care of that condition; however, it has the disadvantage that the engineers cannot be convinced of its practicability. We started originally with a two-pump system; that is, a circulating pump in the block and a make-up pump for the condensate. The higher the steam space is, the drier the steam is. We have the system worked-out now so that we can put it on successfully without having to provide a special head.

KEROSENE ENGINE WITH NO WATER IN THE HEAD

CHAIRMAN HORNING:—We are running one system with no water in the head. We burn kerosene and are doing it very nicely; the head contains nothing but wet steam, and we intend to market the engine that way.

The thoroughness with which Mr. Taub and Mr. Saunders have done their work, in the laboratory and in the field, is a good example of excellent engineering research. They have presented the facts in detail and shown the differences in the results obtained. They have drawn their own conclusions but have given the basis for them so that we can draw ours. I commend their papers as an example of good engineering literature.

TRANSPORTATION PLAN FOR DETROIT

IF you live out in Grosse Pointe or Indian Village, a few years from now, in all probability, you will not take your automobile to go into the city to a matinee or for shopping. Probably this is what you will do. A motorcoach will draw up at the nearest curb, which you will board and on which you will ride for several blocks. It will keep close to the curb and stop at every street corner, taking on and letting off passengers.

You, being bound for the center of the city, will not leave the vehicle until you reach a corner where a flight of steps or a graded incline leads to a passageway underneath the sidewalk and across the street. You will descend and follow the passage, which is really a pedestrian subway, to where a flight of steps or an incline lead you to a covered enclosed safety zone placed in the middle of the street a little above the street level.

In a few seconds a street-car will arrive at the north side of the enclosed safety zone, which is really a small depot, and you will walk aboard, without mounting any more steps, as the floor of the "depot" will be on a level with the street-car. The door you will use to enter the car will not be on the outer or traffic-side of the street-car, but will be on the inner-side, away from the traffic.

On your trip downtown you will make but two or three stops, the street-cars being used for express service only. You will pass many motorcoaches carrying those who are going to the nearest depot to board the express cars, or are taking short trips, but you will not be concerned with them, nor with any other traffic on the street, because your right-of-way on car rails will be secure. Your trip to the center of the city will take but about half as long as it now does, on account of this rather elaborate extension of the "skip stop" program that has been generally adopted by the street-railway companies.

When you arrive at the corner of Jefferson and Woodward Avenues at a similar "safety-zone depot" you will walk from the car platform to the depot floor, through the inner-side door of the car, seeing no traffic, and on one level. Then you will descend the steps, or incline, to the sidewalk subway, cross the street to the northeast corner of Woodward Avenue, where you will board another motorcoach and stop at the corner nearest your shopping center. All of this will come to pass daily and thousands of times a day. in the near future, if the solution of the traffic problem proposed by Harry R. Miller and N. J. Shorn is adopted by the City of Detroit.—*Michigan Women.*

Cylinder Bores: Should They Be Honed or Lapped?

THE finishing of cylinder-bores by grinding, honing and lapping, the advantages and disadvantages of the various methods and the manner of performing the operations were thoroughly discussed from both sides of the question by factory representatives of 10 automobile building plants at the regular monthly meeting of the Detroit Section on Dec. 17, 1925. These papers took the form of a symposium, the presentation of which was followed by an animated discussion, various items of additional information being elicited through the customary question-cards that were distributed before the meeting started.

THE LAPPING OF CYLINDER-BORES

BY F. N. THIEFELS[1]

ABSTRACT

LAPPING has been employed since 1921, but special attention is given to the preparation of the bores before the lapping operation, which is merely a smoothing process. When the out-of-roundness or taper exceeds the standard, a salvaging operation is performed with a single-spindle vertical drilling machine using a Hall lap.

Four cuts are taken through the bores. In the last, from 0.015 to 0.018 in. of stock is removed by a bottom-drive floating reamer with straight blades ground with a slight lead. This is known as the Hoeh reamer. It will not follow the hole but cuts its own path, and aids in reaming the bore square with the crankshaft bearings.

The lapping machine is of the multiple-spindle type of the company's own design and is featured by the heart-shaped or constant-speed cam used for the stroke of the head. This is superior to a crank motion, for it eliminates the dwell at the end of each stroke which has a tendency to bell-mouth the bores. A bushing-plate immediately above the cylinder-block is equipped with soft replaceable bushings. The speed of lapping is approximately 200 r.p.m. with about 100 strokes per min. An aluminum body receives the hones, pressure on which is applied by coiled springs. Approximately 250 cylinder-blocks are lapped on each set of hones at a cost, including labor, of $0.05 per block. The time required for lapping Knight-engine sleeves is from 30 to 45 sec. during which from 0.0005 to 0.0010 in. of stock is removed at a cost of about $0.0125 per sleeve, so that the combined engine cost for 12 sleeves is $0.1500.

THE Wilson Foundry & Machine Co. has been lapping cylinder-bores continually since 1921 and still employs the same method with which it began. We do not concentrate so much on lapping as we do in the preparation of the bores before lapping. We have found that to lap successfully, it is necessary to ream a round, smooth and straight bore. The lapping operation then becomes merely a smoothing process. As stated, the bores must be reamed correctly to speed-up the operation of lapping, and we find therefore that it is necessary to remove only approximately 0.0005 in., which requires from 15 to 20 sec. for cylinder-blocks.

In the final reaming-operation, we hold bores to not more than 0.0005-in. out-of-roundness and not more than 0.0005-in. taper; the production lapping-operation does not round-up nor straighten the bore. When bores are out-of-round and tapered in excess of our standard we perform a salvaging operation with a single-spindle vertical drilling machine, on which is used a Hall or Hutto lap that expands equally on all hones and removes a certain percentage of the taper or out-of-round condition.

We have experimented with various other types of lap and hone and believe that the cost of lapping would be greatly increased if we adopted them and that we should probably experience a let-down in the accuracy of the boring operation. We are, however, still experimenting.

We take four cuts through the bores. The first removes all scale; the second removes about 1/16 in. on a side. Wetmore rough-boring heads are used on the first and second cuts. The cutter speed on these operations is approximately 75 surface ft. per min. with a feed of 3/32 in. per revolution. On the third cut we use our own make of boring-head which has six or eight blades about 2½ in. long set straight into the body, is ground like a rose reamer and is of the end-cutting type. The sides of the blades are circle ground, and are backed off to a narrow land. We remove approximately 3/64 in. on a side by this cut; the speed is about 30 surface ft. per min.; the feed, about 3/32 in. per revolution. In the final reaming-operation, we remove from 0.015 to 0.018 in. and use a bottom-drive floating reamer with straight blades ground with a slight lead. This reamer is called the Hoeh reamer and is patented. It will not follow the hole but will cut its own path, and aids in reaming a bore square with the crankshaft bearings, depending on the accuracy of the fixture. The cutting-speed is about 25 surface ft. per min.; the feed, from 3/32 to ⅛ in. per revolution.

We use Foote-Burt-type boring-mills exclusively. The spindles are guided in a bushing-plate in the top of the fixture on first, second and third-cut machines only.

The lapping machine is of the multiple-spindle type, of our own design, and built for us by the Foote-Burt Co. One of the features of this machine is that a heart-shaped or constant-speed cam is used for the stroke of the head, which carries the laps. This is superior to a crank motion, for it eliminates the dwell at each end of stroke, which has a tendency to bell-mouth the bores. The machine also has a bushing-plate located immediately above the cylinder-block that is equipped with soft replaceable bushings. When the spacing of the bores allows, we use revolving bushings that turn with the lap. These bushings are the same size as that of the cylinder-bores and retain the hones in the lap when the machine is idle.

[1] Engineer, Wilson Foundry & Machine Co., Pontiac, Mich.

The operator, when the lapping has been finished, disconnects the stroke mechanism and draws the laps upward out of the bores into the bushing. The speed of lapping is approximately 200 r.p.m., with about 100 strokes per min.

The lap is an aluminum body having a series of slots for receiving the hones. The pressure on the hones is applied by coiled springs, the weight varying from 8 to 10 lb. per spring with the wear of the hones. We use four springs under each hone, the number of hones in each lap depending on its diameter; the majority, however, have five hones. These are either ¾ in. square and solid, or grooved. The length is either 6 or 8 in., depending on the length of the bores which are to be lapped.

The grooved hone cuts more quickly and is used only on Knight-engine sleeves where speed of operation is desirable. We can lap approximately 250 cylinder-blocks on a set of lapping-hones at a cost, including labor, of $0.05 per block.

On the Knight-engine sleeves, the lapping time is from 30 to 45 sec., depending on the amount of stock to be removed. We allow from 0.0005 to 0.0010 in. per sleeve. The cost of lapping is approximately $0.0125 per sleeve so that the combined engine-cost for 12 sleeves is $0.1500.

A liberal supply of kerosene oil is flowing at all times directly on the laps when they are in operation. This oil washes all the particles of the compound into a pan at the bottom of the machine. The kerosene oil is pumped from this pan into a filter overhead, so that clean kerosene oil is fed to the laps by gravity directly from the filter.

FINISHING CYLINDER-BORES

BY A. R. FORS[2]

ABSTRACT

Early attempts at lapping cylinder-bores were unsatisfactory because of the abrasive material left in the bore; and resort was again made to grinding. Experimental work was also done with the rolling or burnishing process, but it was never used in production.

Objections to grinding include (*a*) the "fuzzy" finish, left by a small wheel rotating at high speed, which is worn away quickly and requires early regrinding; (*b*) the tendency of the grinding-wheel to produce chattering, especially if hard spots are encountered; (*c*) out-of-roundness on account of the heat produced; (*d*) need of specially trained operators, who are sometimes difficult to obtain; and (*e*) the constant attention required from an experienced repairman, to keep spindles and other parts in good condition.

In finishing cylinder-bores at present, the first machining removes ⅛ in. of stock, increasing the bore from 2⅞ to 3 in. in diameter; it is then bored to 3 1/16 in., to straighten the bore, and rough reamed, leaving from 0.015 to 0.018 in. of stock for the reaming to size. The size-reaming is performed on a single-spindle machine so that the holes in the same block shall be uniform in size. The final lapping operation removes about 0.0015 in. To obtain a correctly reamed bore the grinding of the reamer and the hardness of the blades are important.

After trying various types of lap without success, a Hutto lap or grinder proved satisfactory, which in a modified form is at present in use, namely, a six-stone lap with a double three-point-contact support for the stone. This arrangement makes the grinder self-aligning and self-centering, and compensates for uneven wear of the stones caused by lack of uniform density in their composition. Reaming and lapping together consume 14.6 min. which shows a decided saving in labor when compared with the 54.0 min. formerly required for grinding. The finish produced by lapping is said to be better and more accurate than that of grinding and to obtain at a lower labor-cost.

Definite information is not available as to how cylinder-bores were finished previously to 1906 when the Continental Motors plant was moved from Chicago to Muskegon, Mich. In 1906, the bores of all cylinder-blocks were honed on Heald internal-grinding machines. In 1915, the cylinder-bores on one of the high-production engines were reamed and lapped.

Generally speaking, the application of some sort of abrasive such as diamond dust, powdered glass, emery, or carborundum, to a comparatively soft-turned plug, such as lead, brass or cast iron, and then the rubbing of the surface thus "loaded" against another surface to be smoothed or trued, constitute the process known as lapping. In our early attempts at lapping cylinder-bores, a cast-iron split lap was used with a spring-tension, and emery was employed as an abrasive. The laps were driven by a power-machine of the walking-beam type that allowed two blocks to be lapped at the same time. If the bore were out-of-round at the beginning, the lap would follow the bore and the error would not be corrected. We found that the abrasive left in the bore was objectionable. This method, therefore, was discontinued and resort was again made to grinding on this model.

Some experimental work has been done with the rolling or burnishing process. The tool consisted of hardened-steel rollers mounted in an expandable floating carrier driven by a power-machine. This was never used in production, however, for a round true bore could not be produced.

The principal objections to grinding cylinder-bores on a standard internal-grinding machine are:

(1) Grinding with a small wheel rotating at a high speed produces a "fuzzy" finish that is worn away quickly and requires an early regrinding of the bore

(2) The grinding-wheel is not supported rigidly enough and the tendency is to produce chattering, especially when hard spots are encountered in the bore

(3) Grinding dry produces an out-of-round bore, due to the heat generated

(4) The machine requires specially trained operators; at various times, we have found it difficult to maintain production because of a lack of capable operators

(5) Grinding-machines require more constant attention from an experienced repairman than any other production equipment, to keep the spindles and other parts of the machine in condition to produce satisfactory results

The following information pertains to the condition under which we are finishing cylinder-bores at our Detroit plant at present. The work was begun in August, 1923. We do not feel that we have the "last word" in equipment for finishing cylinder-bores, but we believe

[2] M.S.A.E.—Production engineer, in charge of tools, methods and equipment, Continental Motors Corporation, Detroit.

that information will soon be submitted that will aid in developing equipment to meet present-day needs.

Let us take for example a six-cylinder block with $3\frac{1}{8} \times 7\frac{1}{4}$ in. bores. The cylinder-block is received from the foundry with a core $2\frac{7}{8}$ in. in diameter. In the first machining operation of the bore it is rough-bored to a 3-in. diameter, the excess stock only being removed. In the second operation it is bored to 3 1/16 in. to straighten the bore. In the third operation it is rough-reamed, leaving from 0.015 to 0.018 in. stock for size reaming. In all these three operations, we pilot the boring-bars at the top and bottom to ensure a straight bore.

Our size-reaming operation is performed on a single-spindle reaming-machine, one operator running four machines. The reason for using a single-spindle machine is that holes of uniform size shall be produced in the same block. We use a spindle speed of 40 r.p.m., a feed of 3/32 in. per revolution and an eight-blade left-hand spiral-reamer that allows the cylinder to float. It is very important that the bore shall be accurately reamed for size and finish. A six-bore cylinder-block is reamed in 5.6 min. with one man operating four machines. We leave 0.0015 in. for the final finishing or lapping.

An important point in obtaining a correctly reamed bore is the grinding of the reamer. We experienced considerable difficulty at the start and much experimenting was required but, through information received from other plants, we worked out a method of grinding that was suited to our conditions. The hardness of the reamer blades is also important. We use high-speed-steel blades of 77 to 82 scleroscope-hardness.

I shall refer to our present method of finishing cylinder-bores as "lapping," as it is generally known by that term, although I have shown previously in a description of lapping that this is not correct. Our lapping of cylinders is performed on a single-spindle machine using a spindle speed of 400 r.p.m. and a hand-feed. As it is better to have a machine-feed, we have under construction at present an attachment that will accomplish this result.

The first lap that we used had an aluminum body carrying five $\frac{3}{4} \times \frac{3}{4} \times 6$-in. stones held against the cylinder walls by spring-tension. This did not correct errors in the reaming operation and usually left the bores bell-mouthed at the top, caused by withdrawing the lap. Various other laps on the market were tried with no greater success. In November, 1923, we adopted the Hutto lap or grinder for production. I might say that we were the pioneers in using this type of lap in production. The first Hutto lap that we used was a three-stone type with a screw-driver adjustment that was designed for service work. While we were trying other types of lap, one of these was brought into our plant and was so successful from the start that we used them even in their original design. We soon found, however, where they could be improved and made suggestions to the Hutto company accordingly. These suggestions, worked out and tested in our plant, led to the product that we are using at present.

This lap is a six-stone type embodying a double three-point-contact support for the stone. This three-point-contact principle for arranging the stones makes the grinder self-aligning as well as self-centering. These features result from the fact that the two adjusting-cones and stone-holder pins that rest upon them have certain limited freedom in which to float until the cutting-surfaces of the stone are all parallel. This floating of the adjusting mechanism also compensates for uneven wear of the stones caused by lack of uniform density in their composition. We have found that this lap will produce a round accurate bore and correct any errors that may exist after reaming. A stream of kerosene is directed on the stones and carries away all loose particles of metal and abrasive material from the grinding surface as soon as they are released.

The bores are held to a limit of 0.0005-in. out-of-roundness and from 0.0005 to 0.0010-in. taper. The taper, if any, must of course be larger at the bottom of the bore. A cylinder-bore is lapped in 1.5 min., or 9.0 min. for a six-cylinder block. As I have stated above, a cylinder-block is reamed in 5.6 min., making a total of 14.6 min. for both reaming and lapping. Grinding a cylinder-block of the same size required 54 min., so a decided saving in direct labor has been made in favor of our present method.

When production warrants it, a multiple-spindle lapping-machine could be used successfully, although I do not think one is on the market at present which fulfils all the requirements. A number of firms are working on lapping-machines and expect to solve the problem very soon.

We believe that in our lapping operation we are getting a finish that is better and also more accurate than grinding. We are getting a better cylinder-bore at a lower labor-cost by our present method than we did by grinding.

FOUR YEARS OF CYLINDER-BORE LAPPING

BY R. A. DEVLIEG[3]

ABSTRACT

PRELIMINARY tests having proved that lapping produced a better finish than grinding at lower cost and did not require skilled operators on the finishing operation, the practice of lapping was adopted after a few months and has been continued for more than 4 years.

The lapping is done in two operations, roughing and finishing, the type of lap being the same but the stones varying in length, shape and degree of fineness. Multiple-spindle machines rotating at 275 r.p.m. and reciprocating at 40 strokes per min. remove from 0.0005 to 0.0015 in. The length of the stroke corresponds to that of the piston used in the cylinder. Lapped cylinders leave the running-in stands in very satisfactory condition. The investment in lapping equipment being only a fraction of that required for grinding and the labor costing less, lapping is considered an outstanding contribution to the economies of the industry.

THE experience of the Chrysler Corporation with cylinder lapping covers a period of more than 4 years. After some preliminary tests with improvised equipment, it was decided that lapping would produce a better finish than had been obtained by grinding, at a lower cost, and would have the added advantage of eliminating the necessity for keeping skilled operators on the finishing operation. For a time, the grinding oper-

[3] M.S.A.E.—Engineer of production, Chrysler Corporation, Detroit.

ation was continued on cylinder-blocks for certain engines but, a few months later, after comparing results and costs, the practice of lapping was fully adopted.

Cylinders are lapped in two operations, roughing and finishing. The type of lap used for the two operations is the same, except for the length and the shape of the stones on the cutting-surfaces, the stones for the roughing operation having a concave surface with lands approximately 1/8 in. wide; the finishing stones, a convex surface of the same contour as the cylinder-wall. In the latter case, the stones are of much finer grade than those used for roughing and are approximately the full length of the holder, whereas the roughing stones are approximately one-half the length of the holder. Two stones are used, placed end to end in each groove of the holder, the number of grooves in the holder depending on the diameter of the cylinder to be lapped. The stones are backed with coiled springs, to give the desired pressure against the cylinder-walls.

Multiple-spindle machines that have a rotating speed of 275 r.p.m. and a reciprocating speed of 40 strokes per min., are used the length of the stroke corresponding to the stroke of the piston used in the cylinder. A liberal supply of kerosene is pumped into each cylinder to keep the stones cool and cutting freely.

The quantity of material removed by the two lapping operations varies from 0.0005 to 0.0015 in., depending on the condition of the surface produced in the reaming operation just preceding the lapping. It is very essential, however, that the surface be smooth and that the cylinder be within very close limits of being round and without taper. The laps described above, which have been used for a long time, do not fully correct out-of-round or tapered bores, so that the importance of having the bores accurately machined and smooth before lapping is evident. During the last few months some tests have been conducted with laps now on the market, which are designed to correct variations in the cylinder dimensions. These tests are still under way and no definite data on the results can be supplied at this time. Experience has proved very conclusively that engines with lapped cylinders leave the running-in stands with the bores in very satisfactory condition, which, in reality, is the most important factor in determining the methods to be used. The investment in lapping equipment is only a small fraction of that required for grinding and the saving in direct labor is such as to make lapping one of the outstanding changes in methods of machining that have contributed to the economies in the industry of which the buyer has received the benefit.

THE HONING OF CYLINDER-BORES

BY H. C. MILLER[4]

ABSTRACT

ALL cylinder-bores in the Oakland Six and Pontiac engines are honed. A five-stone hone with seven coiled springs beneath each stone gives a pressure of from 75 to 100 lb. against the wall of the cylinder. Bell-mouthing is overcome by the occasional use of a scrap block, which prevents the hones from flying out. The reaming and honing operations consist of a rough, a semi-finish and a finish reaming, and a rough and a finish honing. The speed of the rough hone is 275, and of the finish hone 160 strokes per min. on a single-spindle machine, each bore being given one pass.

ALL cylinder-bores in the Oakland Six and Pontiac engines are honed, because we have found that in this manner an accurate bore can be economically produced with a finish and wearing quality superior to that produced by any other method that we have tried or seen.

A good reaming job previously to the honing operation is absolutely essential to the final desired result. Any out-of-round condition that appears in an occasional bore is traced back immediately to the reaming operation and correction is made at that point before another block is machined.

The sequence of machining operations carried out at this plant is as follows: (*a*) rough reaming, (*b*) semi-finish reaming, (*c*) finish reaming, (*d*) rough honing, and (*e*) finish honing. We use a five-stone hone, each stone being held against the cylinder wall by seven coiled springs having a pressure that varies from 75 to 100 lb. as the stones wear. The stones used in the rough-honing operation are medium-grade, and those in the finishing hone, fine-grade.

Kerosene is used as a lubricant. The speed of the rough hone is 275 strokes per min. The speed of the finishing hone is 160 strokes per min., with hand operation.

The rough honing is done in a semi-automatic multiple-spindle machine; the finish honing, is a single-spindle hand-operated vertical drilling-machine.

To overcome any tendency to "bell-mouth" during the honing operation, we arranged a fixture that, for the Oakland Six, holds a scrap block directly over and close to the block that is being honed. This keeps the stones from spreading out, when leaving the top of the bore, and prevents bell-mouthing. For the Pontiac, in which the block and case are cast together, a fixture carrying bushings is used for the same purpose.

The results obtained by the above method are uniform and consistent and the desired finish can readily be produced with an accuracy inside the established limit of 0.0005-in. out-of-roundness and taper.

HONING LINCOLN CYLINDERS

BY O. E. HOVEY[5]

ABSTRACT

GRINDING is believed to be the only way in which to get a straight bore. Lincoln cylinder-blocks Brinell at 225. After performing three boring operations on the bore, from 0.004 to 0.006 in. is left for grinding stock. Six or seven reciprocations bring the block down to size. Nothing is left for honing. On the honing machine the lap is reciprocated straight up and down. The hone used is similar to that used by the Dodge organization. As the honing disclosed spirals, waves and chatter-marks, it was found that more care must be taken with the grinding. Special stones are

[4] Assistant superintendent of the engine and axle division, in charge of manufacture and tools, Oakland Motor Car Co., Pontiac, Mich.

[5] Tool engineer, Lincoln division of the Ford Motor Co., Detroit.

used in honing. These are furnished by the Carborundum Co. Because of the hardness of the block, the stones become glazed after five or six cylinders have been honed but the glaze is removed by reciprocation for ½ min. in a rough-bored block. The aluminum-alloy piston Brinells at 160. The fact that this material is a little softer than that formerly used is one of the reasons for honing the bores rather than using the pistons for lapping. A 5 to 6-hr. block-test eliminates scratches and scorings and also the wear on the piston.

WE may be a little old-fashioned, as we still grind cylinder-bores. But to get a straight and round bore is difficult. So far as trying to get a straight bore without grinding or deflection of the spindle is concerned, I do not see how it can be done in any other way. I believe the only way is to grind. In the first place, our cylinder-blocks Brinell at 225, which is a trifle harder than the average block. When they first came through we found fault with the engineers naturally, as we were on the production end, but our troubles soon ended and all agreed on the better block.

We perform three boring operations on the bore. From 0.004 to 0.006 in. is left for grinding stock. When the cylinder-block is passed to the grinding-machine, the operator stamps his number on it after the grinding operation has been completed. The blocks are reciprocated on the wheel six or seven times before they get down to size. We leave nothing for honing, as we are interested only in removing the grinding fuzz and laying the grain.

Then the block is passed on to the honing-machine, which is of our own design. The lap is reciprocated straight up and down, in the same manner as the piston except that the bottom of the stroke is indexed unevenly to break up the path of the stones. A series of tests was made on these operations. We began by using the revolving type, but found that it did not lay the grain and take the "fuzz" off in the direction needed but left practically the same load against the piston. We therefore took the next step, that is, one-quarter turn on the downward stroke, and found this a little better. The chief reason that this operation was discarded was the amount of bearing, as shown by a special blued plug-gage 14 in. in length. This test was made not only on seven or eight blocks but on hundreds in series. The reciprocation on our machine is about 125 strokes. The hone, having a 2-in. face and being approximately 8 in. long, is of our own design and is similar to that used by Dodge Bros. Three stones, having a radial pressure of approximately 25 lb. are used, and a coiled spring in the center bears against the two outer cones on the end. The two outer cones bear against two cams fastened to the retainer of the hone. The operation requires approximately 2 min. When we began to hone we found that we could not be careless with the grinding. We found conditions that we had never found before: spirals, waves and chatter-marks. We had to hold the grinding down more. Those conditions caused us to give each operator a certain number and, when poor conditions were disclosed in the honing, the grinding-machine was immediately shut-down and a check was made of the machine.

Our machine is approximately 6 ft. high. We use the crankshaft and connecting-rods for reciprocating the hones. Realizing that clean lubricant is necessary to prevent scratching, the reservoir for kerosene was placed in the base of the machine. A pump in the corner of the base causes the kerosene to flow to the hone and, as the hard particles from the honing are passed through the cylinder-block, they reenter a channel around the base. Here are located about seven or eight baffles varying approximately ½ in. in height, so that the hard particles settle to the bottom and clear kerosene is available for the hones when operation is begun again.

The stones are furnished by the Carborundum Co. and cost a little extra because they diamond off the stones so that full bearing contact is obtained to start with. They use a solid dummy holder, a duplicate of the expanding type used on blocks.

In honing so hard a block, the stone becomes glazed, after possibly five or six cylinders have been honed, so, a rough-bored cylinder-block is placed in the machine and is reciprocated for possibly ½ min. to remove the glaze.

The piston is of aluminum alloy and Brinells at 160. That is one of the conditions which induced us to hone. This material is a little softer than we were using before. What we desired was to build an engine without using the pistons for lapping. We found that by using the revolving type and one-fourth turn, a certain amount of load was necessary against the piston to lay the grain in the proper direction. The straight up-and-down movement was therefore adopted. In the proper inspection of our engines, which undergo a block-test for from 5 to 6 hr. and are not run in but are put under load from the start, we eliminate the unsightly scratches and scorings that might occur and, most important of all, the wear of the piston.

It is generally admitted that it is hard to bore a cylinder straight within 0.0005 in., especially with a multiple-spindle machine. I have seen it practiced and have tried it myself. But that is not producing a straight bore. We still depend upon the boring-machine for roughing. If hard spots occur, I do not know how they can be taken out if the grinding-wheel does not do it. I hope that in the near future some one will be able to design a multiple grinding-machine that will reduce the expense of grinding. I believe that even the cheapest cars will soon be grinding the cylinder-bores and will realize that compression is everything.

The Lincoln Motor Co. in servicing the blocks makes an allowance on the new block when the old one is returned. The worn ones are reground at the factory for service use only, thereby avoiding any chance of a good engine being ruined by a careless garage workman.

METHODS OF FINISHING CYLINDER-BORES

BY VICTOR COLLIAU[6]

AFTER three successive boring operations, the piston-bores are finish reamed on a Baker single-spindle machine of the floating type with high-speed-steel blades running at approximately 30 ft. per min. Honing is performed on a six-spindle Moline honing-machine using Titan hone bodies carrying four 1 x 8-in. honing-sticks. The bore is enlarged about 0.002 in. Any bores that do not comply with the finished specifications are made to do so on a single-spindle vertical drilling-machine having an indexing-fixture. In measuring the bores, the micrometer measurement is transferred through a system of levers to a dial indicator reading in ten-thousands.

[6] Sales and production manager, Kermath & Whitcomb Co., Detroit.

When the grinding-machines are in good condition and properly set up, ground bores are more uniformly square than those reamed and honed; otherwise, the latter should be more accurate. The most desirable finish is obtained by honing both the ground and the reamed bores. If all grinding-wheel or reamer marks are removed by honing, it is impossible to distinguish between ground and reamed bores, and the same excellent finish can be obtained in either way.

The same accuracy cannot be obtained on a production basis with grinding as with reaming. With reaming and honing, the floor-space required is less and the investment in equipment, the labor cost and the cost of up-keep are lower.

A DESCRIPTION of all the operations on our cylinder-blocks that pertain to finishing the bores includes (*a*) milling the manifold side, (*b*) milling the top and the bottom and (*c*) drilling and reaming the dowel-holes in the bottom face.

The sequence of the various minor operations is as follows:

(1) The piston-bores are bored to between 3.130 and 3.135 in. in diameter, locating from dowel-holes in the bottom face, one six-spindle Foote-Burt machine with spindle guide-bushings above the cylinder-block being used

(2) The piston-bores are bored to between 3.180 and 3.185 in. in diameter, using the same equipment as in the previous operation

(3) The piston-bores are bored to between 3.235 and 3.238 in. in diameter on a six-spindle Moline machine with the bars running in guide-bushings above and below the cylinder-block, using both Gisholt and Kelly boring-tools, which are ground in place in the bars. In this operation the bores are brought within 0.010 or 0.012 in. of the finished reamed size and are bored square with the bottom of the block. After this operation and before the bores have been finish reamed, the remaining machining operations are completed. The block is then washed and is finish reamed while warm

(4) The piston-bores are finish reamed to between 3.2470 and 3.2475 in. in diameter on a Baker single-spindle machine. The block is located and indexed from bore to bore accurately within approximately 0.010 in. The reamer is of the floating type with high-speed-steel blades running at approximately 30 ft. per min. and feeding from ⅛ to 3/16 in. per revolution. Bores are reamed straight and round within 0.0005 in. and are free from scratches and chatter-marks. We ream from 200 to 400 bores per grinding of the reamer

(5) Bores are honed on a six-spindle Moline honing-machine, using Titan hone bodies. Each body carries four 1 x 8-in. honing-sticks. In this operation the bore is enlarged approximately 0.002 in., the intention being to finish the bore at this time. Our finished size is from 3.2485 to 3.2500 in. and the bore must be straight and round within 0.001 in. All reamer marks must be removed and the bore hones must be smooth and free from scratches

(6) Any bores that do not comply with the finished specifications are made to do so on a single-spindle vertical drilling-machine equipped with an indexing-fixture. The number of bores that require finish honing varies. Both Hutto and Council hones are used for this finishing operation

In the Titan hones, we use carbonundum 60-G-2 or GO-4 or C.P. Desano C-46 K. In the Council hones, we use 120-G-3 or G-4 carborundum sticks that were bought for the Titan hones. In the Hutto hone we use mounted sticks furnished by the Hutto Company.

For measuring the bores, we use an indicator that gives a micrometer measurement directly across the bore. Through a lever arrangement, the measurement is transferred to a dial indicator reading in ten-thousandths. This instrument was developed by E. Warren of our engineering department and is believed to be more accurate than the commonly used type that indicates one side of the bore only.

Cylinder-bores should be accurately located, square with the crankshaft, straight, round, and to size within reasonable limits. When the grinding-machines are in good condition and properly set-up, bores will be ground uniformly square and usually more accurate in this respect than when they are honed and reamed. In all other respects reamed and honed bores should be more accurate; and we have found them to be so. It is common practice to hone both the ground and the reamed bores to obtain the most desirable finish.

If all grinding-wheel or reamer marks are removed by honing, it is impossible to distinguish between ground and reamed bores. I feel justified therefore in saying that the same excellent finish can be obtained in either way.

We have been reaming holes straight and round within a limit of 0.0005 in.; the variation in size is also within this limit of 0.0005 in. We have never been able to duplicate this accuracy on a production basis by grinding. We prefer reaming to grinding, therefore, when a perfect honed finish is required.

The floor-space required for reaming and honing is much less than for grinding. Investment in equipment, labor cost and cost of up-keep also are lower.

After reaming and honing for several months, we reverted to grinding. By using all the equipment we had installed for reaming and honing, we were able to ream to within 0.004 in. of the finished size and to grind on this amount of stock. We reduced the cost of the grinding operation from $0.60 to $0.40 per block. Then, by adding two unskilled operators to the reaming and honing squad, at a cost of $0.15 per block, we eliminated the grinding operation; in this way we reduced the labor cost $0.25 per block.

For multiple-spindle reaming, or if the reaming-blocks are too heavy to float readily in the single-spindle reaming operation, I would recommend such reamers as are used by the Wilson Foundry & Machine Co.

It is common practice to ream on four-spindle machines with non-floating reamers. This is possible when the machines for the various operations are exact duplicates insofar as the alignment of spindles is concerned. Such machine accuracy is difficult to maintain and I doubt whether the best results can be obtained in this manner.

For production up to 15 or 20 blocks per hr. I prefer single-spindle machines; for finish reaming on mass production requiring two or more multiple-spindle machines, the single-spindle machines show a higher labor-cost and require more floor-space.

RESULTS OBTAINED IN LAPPING CYLINDER-BORES

BY DAN SMITH[7]

ABSTRACT

DIFFERENCES of opinion as to the best manner of performing the lapping operation are due to difference in the manufacturing tolerances for out-of-roundness, taper and finish, which, in turn, are governed more or less by the price of the car.

Four reaming operations are performed on cylinder-blocks and include rough, first and second semi and finish reaming with multiple-spindle machines. The finish reamers are of the floating type with six left-hand-spiral blades, and operate at 45 r.p.m. with 3/32-in. feed. The stock removed on this finish-cut is 0.012 in., leaving 0.002 or 0.003 in. for lapping, which is considered necessary to remove all traces of feed-marks. The positive type of lap with cone adjustment is considered the best. The spindles rotate at 360 r.p.m. with 55 reciprocations per min., giving the lap a spiral cutting-action. The tolerance allowed is 0.00025 in. for out-of-roundness and 0.00050 in. for taper. A single-spindle machine is used to correct any errors that may be found after the block has come from the multiple-spindle machines.

Two men can lap 135 eight-cylinder blocks per day, as compared with 28 by grinding. The maintenance cost of lapping is greater, however, due largely to trouble with the stones, which wear unevenly, crack, load-up and glaze. This trouble is attributed to errors in reaming and to the hardness of the castings. The expected economy has not yet been achieved but a better finish and closer limits are obtained.

ALTHOUGH the production of lapped cylinder-bores has attracted particular attention throughout the automobile industry, considerable difference of opinion seems to exist as to the best method of performing the operation. Much of the varied practice is due to the difference in manufacturing tolerances for out-of-roundness, taper and finish, which perhaps are governed more or less by the price of the car. Our present method has been adopted after considerable experimental work on various speeds, reciprocations and designs of lap.

Our cylinder-blocks are reamed in four operations; rough, first and second semi, and finish reaming. Each operation is performed on a multiple-spindle machine. The finish reamers are of the floating type with six left-hand-spiral blades, and operate at 45 r.p.m. with a 3/32-in. feed. The stock removed on this finish-cut is 0.012 in., leaving 0.002 or 0.003 in. for lapping. Although this is more stock than some manufacturers leave, we find this amount to be necessary in order to remove all traces of feed-marks.

The lapping is performed on a four-spindle machine for the eight-cylinder block and on a three-spindle machine for the six-cylinder block. The work is shifted for alternate bores on account of the wide center-distance required for our style of lap.

Our experience with various types of lap has shown that the positive type with cone adjustment is the best for our conditions. The cones are operated by a threaded shaft connected to an operating-collar 6 in. in diameter. Each lap carries six stones ½ in. wide by 4 in. long, made of carbide of silicon, 120 grit. The operator enters the laps into their respective bores by raising the machine table. He then opens each lap against the cylinder-wall and starts the machine. The spindles rotate at 360 r.p.m. with 55 reciprocations per min. The stroke is 5½ in. for a bore 3 in. in diameter by 7¼ in. long. It will readily be seen that the lap has a spiral cutting-action. All four laps move up and down in the same plane under a constant flow of kerosene.

Midway on the downward stroke the adjusting-collar makes contact with two bronze shoes that have an adjustable spring-tension and are located on the bushing-plate in such a manner that they form a V. These friction shoes maintain the cutting-tension until the operating-collar touches the stop. The stop has micrometer adjustment, making it convenient for the operator to compensate for the wear of the stones. In stopping the spindles at the top of the stroke, the collar makes an extra turn under its own momentum and automatically releases the tension.

With this method of lapping, we get an excellent finish, from which all feed-marks are removed. Our tolerance is 0.00025 in. for out-of-roundness and 0.00050 in. for taper. To maintain these limits, we find it necessary to use a single-spindle machine with the same type of lap to correct any errors that might be found after the block has come from the multiple-spindle machines.

Two men can lap 135 eight-cylinder blocks per day; whereas our record cards show that two men ground 28 per day. The maintenance cost of lapping, however, is much higher than that of grinding, because of the heavy load on the machine and the short life of the stones. The mechanical part of the lapping operation is very satisfactory, most of the trouble being with the stones. We find that they wear unevenly, crack, load-up, and glaze. Much of this trouble is attributed to errors in reaming and to hardness of the castings. The operator dresses the stones after every eight blocks.

Up to the present we are unable to achieve the economy that was predicted for this operation but, with the better finish and closer limits, we favor the continuation of the present method and are giving it constant attention in an effort to lower the cost without detracting from the desired results.

HONING CYLINDER-BORES

BY J. G. HAMMOND[8]

ABSTRACT

LAPPING has been found unsatisfactory on a production basis and the final finish is secured with carborundum hones; but the more accurately the bores are machined before honing, the better will be the final result.

Following a rough reaming operation, that removes about ⅛ in. of stock, two straightening operations that remove 0.050 in. in the first and 0.030 in. in the second, and a finish reaming that removes from 0.010 to 0.012 in., the bores are honed twice, the first with a medium-grade hone and then with a fine-grade carborundum

[7] Foreman, line-eight machine shop, Hupp Motor Car Corporation, Detroit.

[8] Assistant superintendent of the engine plant, Buick Motor Co., Flint, Mich.

hone. The speed of honing is 350 r.p.m. while the hones move up and down. The time required is about 2 min. and the amount of stock removed is from 0.0002 to 0.0004 in. in each operation. After every 20 blocks the hones are redressed with carborundum grit on a cast-iron surface-plate.

WE do not use a lapping process in the finishing of cylinder-bores. We have tried a copper lap and lapping paste and also cast-iron laps, but the results have been unsatisfactory on a production basis.

The final finish is secured with carborundum hones but the more accurately the bores are machined before honing, the better will be the final results that are obtained. For that reason, I shall precede the description of the honing method by a description of the machining operations.

The first operation is rough reaming, which is performed on six-spindle vertical machines, and removes slightly more than 1/8 in. of stock. The next two are straightening operations in which about 0.05 in. of stock is removed in the first and 0.03 in the second operation. This is done by six-spindle horizontal boring-machines, using boring-bars piloted at each end.

The next operation is the finish reaming, which is performed on six-spindle vertical machines having floating spindles, from 0.010 to 0.012 in. of stock being removed. The bores in the finish reaming are held to limits of 0.0020 in. for diameter, 0.0005 in. for out-of-roundness and 0.0005 in. for taper. The squareness of the bore with the base is held within 0.002 in. in the height of the block.

The bores are then honed in six-spindle vertical machines, floating spindles being used so that the hones are free to follow the bores. The hone-holder is made of aluminum and holds five carborundum hones, which are 5/8 in. square by 6 in. long and which, when in the bore, are held against the cylinder-walls by springs behind each hone.

The blocks are honed twice, first with a medium-grade hone, then are finished with an F. F. fine-grade carborundum hone, using kerosene for a lubricant. The hones revolve 350 times per min., also moving up and down. The time per block is about 2 min. for each operation. The amount of stock removed is from 0.0002 to 0.0004 in. in each operation. If an attempt is made to remove much stock with this style of lap, the inaccuracy of the bore will be increased.

Honing does not correct the taper or out-of-roundness. It does smooth-up and improve the finish of either a reamed or a ground bore. As the corners of the hones wear to the contour of the bore, the hones become dull and glaze and sometimes load; consequently, they are removed after every 20 blocks and are redressed to a flat surface with carborundum grit on a cast-iron surface-plate and are then cleaned so that they will cut freely.

We have experimented with various types of lap and hone that have been submitted by tool manufacturers at different times. These have had different spring arrangements but none have given better results than the one just described.

It is not difficult to hone a cylinder-wall but, in the honing process, if springs are used in the holders, the hones will be free to follow the walls and the inaccuracy of the reaming will be more likely to be increased than reduced.

THE DISCUSSION

QUESTION:—Does the Wilson Foundry & Machine Co. hone the inside of the inner and the outer sleeves and also the cylinder-block?

F. N. THIEFELS:—We hone all the cylinder-blocks on the poppet-valve and the Knight engines; also the bores of the inner and the outer sleeves of the Knight engines. We grind the outside of the sleeves.

QUESTION:—Why is wear not considered more important in the method of finishing? Why neglect service methods?

A MEMBER:—I should like to answer the first part of the question. Several manufacturers are honing. In the case of Lincoln, it is only a smoothing operation, because we do not take out any stock to get a perfect surface, the kind of surface that one gets after driving an ordinary 5000 miles. The reason is that it is imperative to have a perfectly smooth mirrorlike surface in the cylinder. If it is not aluminum-alloy, the piston will wear-down quickly. They Brinell occasionally up to 175 and always to 160. The life of the piston will be greatly shortened if the surface is not perfectly smooth. We should not put in a honing operation for any reason except to make the surface perfectly smooth, because the greatest accuracy is obtained through very careful grinding. This work was begun in the experimental department and was developed completely before production was considered. After the results had been obtained, the management said they did not care what the cost was, they wanted to do the work in that way. I think what they were aiming at was a perfect job.

M. A. THORNE[9]:—It is pretty generally recognized now that the lubrication of the cylinder-bore is not of the flood type but rather of the boundary type, in which case lubrication is effected by a film of molecular thickness. That such is the case has been pretty clearly demonstrated in the laboratory, and anyone who has serviced worn blocks must have been impressed by the further evidence that the rings occasion, roughly, 75 per cent of the wear. Under these conditions of thin-film lubrication, and particularly with the exclusion of abrasive contaminants, the smoother the cylinder surface, the less the wear should be during the first period of engine use. For this reason, any method such as honing, which produces an initially smooth cylinder-bore, should be preferable to other methods of finishing cylinders that do not give the same degree of smoothness.

QUESTION:—Has anyone conducted tests on the amount of clearance that will develop between the piston and the cylinder after say 1000 miles, with a honed cylinder and with a ground cylinder?

GEORGE E. GODDARD[10]:—Whoever asked that question might make it more definite by stating whether the cylinder and the piston are both of cast iron. It would make very much difference, whether the piston were aluminum, and whether the test were run in a dynamometer-room, where the air is clean, or on the road.

CHAIRMAN L. C. HILL[11]:—Suppose the piston and the cylinder were of cast iron; has anyone conducted such a test? If not, how about the aluminum piston and the cast-iron cylinder?

G. B. EMERSON[12]:—In 1919 and 1920, in connection with my cylinder-regrinding shop, I accumulated some data on the subject of cylinder-wall wear in the day of cast-iron pistons and gravel roads. Wherever possible the car mileage was recorded, as well as the diameter of the cylinder at the top and the bottom. These data showed

[9] M.S.A.E.—Engineer, automotive, Tide Water Oil Sales Corporation, Detroit.

[10] M.S.A.E.—Advisory engineer, Briggs Mfg. Co., Detroit.

[11] M.S.A.E.—Detroit district, automotive sales manager, Valentine & Co., Detroit.

[12] A.S.A.E.—President and production manager, Emerson Motor Parts Co., Detroit.

that the wear was practically constant at a value of 0.001 in. per 5000 miles. This was especially true after the car had been run for 20,000 miles or more. I am sorry that I did not continue to record the same data after the introduction of aluminum pistons.

MR. GODDARD:—More than 1 year ago in a non-stop block-test approximating 5000 miles on the ground bore with a standard cast-iron cylinder-block and standard cast-iron pistons, the piston wore down about 0.001 in. The same test made on a 5000-mile trip around the State of Michigan showed between 0.005 and 0.006 in. of wear. It was for this reason that the lapped bore was developed with a straight vertical reciprocating lap. In tests made under the same conditions with the lapped cylinder-block, the wear during the 5000-mile run in the laboratory test was such that it could scarcely be measured. It was not worth considering. On the same test around the State during the summer under dusty conditions, the piston wear was 0.002 in. The wear on the cylinder-bore could not be measured. No air-cleaner was used.

CHAIRMAN HILL:—Such a test should be run with and without air-cleaners and should determine whether the difference in frictional horsepower and the reduction in wear were sufficient to warrant the additional cost of honing or lapping.

QUESTION:—Is the diameter of honed cylinders the same as that of ground cylinders or is it made slightly larger on account of less wear on the piston and the rings?

A MEMBER:—The finished dimension of the honed cylinder is always calculated from the piston-clearance. If a tight piston-fit is desired, 0.0025-in. feelers are used.

QUESTION:—Has anyone attempted to lap or hone any material other than cast iron, such as steel-lined cylinders?

S. O. ISOM[13]:—Less than 1 week ago we ground, or as some term it, honed some cylinders for the Toledo plant of the Chevrolet Motor Co. These cylinders, which were of seamless steel tubing, 6 in. in diameter and 6 ft. long, had been used on an oil gear-broaching machine. We took out 0.008 in. in 4 hr. and held them inside of 0.001 in. all the way through for taper and out-of-roundness and cleaned up all the reamer marks. Some of these cylinders were then prepared for another broaching test. Previously they had run in jumps, due to waves in the cylinder, but now they move steadily and not in jumps as they did before.

QUESTION:—Do pistons wear more rapidly in lapped or honed cylinders than in those not so finished, on account of the cylinders becoming charged with grit from the laps or hones?

CHAIRMAN HILL:—That refers again to a comparative test of pistons operating under the same conditions in two cylinders that have been finished differently. It would be interesting for someone to test a car, the engine of which had the front three cylinders reamed and the rear three honed and used an air-cleaner. The reason I am so emphatic about the use of an air-cleaner is that variations in the dust content of the incoming air will influence the results greatly. The air-cleaner should ensure uniformity of air conditions.

QUESTION:—Is it practicable, from a garage or service standpoint, to promote honing?

A MEMBER:—The service honing-tool has been the greatest salvation to the service-station which has been brought out for several years. The instrument made by Hutto, which is of the rigid type, has been found more satisfactory, from my experience in the field, than the type controlled by springs at the back. Rebuilt automobiles are frequently viewed in the light of new cars. After a car has run from 10,000 to 12,000 miles, the service-station in installing new pistons must provide cylinder-walls that will give good service. The Hutto machine makes that possible. It produces a very satisfactory honing job in the field.

QUESTION:—Will it take longer for rings that are not perfect to seat in a honed cylinder than in a rough one?

A MEMBER:—Early in our experimental honing, we honed cylinders to a mirrorlike finish and built several engines in that way. When we put them on the block-test, the men complained that they had to run them 3 or 4 days before the rings began to seat.

QUESTION:—After boring, the cylinders are rough ground or rough lapped before being finally smoothed up. What is the cheapest method? What is the quickest?

A MEMBER:—With regard to the finishing of cylinders that are honed, if you get a smooth surface, you will correct all the errors due to low spots and you will have no high spots to wear off. It would be the same as if you were to grind a plug-gage. It would not be in the same class with a lapped gage. After you have used it for a little while, you can see the errors. The reason that plugs are lapped is to get a perfect finish. If you should grind a plug-gage with the very best equipment you still must leave 0.002 in. to clean up.

MR. GODDARD:—I think the question is answered by the fact that the lapping process produces a surface that is equal to 5000 miles of running surface. It has a grain in a vertical direction, which is the same as that produced by the piston. The buyer is given a finished engine. Does anyone believe that lapping does not accomplish that result?

A MEMBER:—We tried some experiments on the seating of rings over a period of about 1 year. A difference exists in the compression. We found that, regardless of whether the rings seat as quickly in a honed as in a reamed cylinder, the wear is the same on an oil jack as on a running test.

MR. GODDARD:—The question of ring pressure has some bearing on the condition of the cylinder-bore. It has been my experience that, previously to lapping, we used higher ring-pressure against the cylinder. I think that was because we expected that the ring would tend to produce a better surface on the cylinder and consequently on the pistons. Our experience has been that, after these lapped surfaces had been produced with ring pressure and the wear had been proved to be appreciably less thereafter, we decreased the ring pressure when adopting the machine-lapped cylinder.

QUESTION:—Does the White Motor Co. believe that the cylinder should wear down the ring so that it will seat, or the ring wear itself down so that it will fit the cylinder?

A MEMBER:—As I understand it, lapping means using a charged lap that produces a very high-grade finish. A service shop that I consider does as fine work as is done in this Country, the Chicago-Cadillac Co., laps as it grinds. It uses a charged lap with a very fine abrasive and wears all the grinding and honing marks off smooth. This produces an actually glazed surface. I wonder whether any of the factory men have experimented with lapping?

A MEMBER:—We experimented with lapping, and found that the charged lap would load the cylinder. Therefore, we discontinued it. If we had any servicing, we found that we could not do it with the lap, as our jobs would all come back and we would be obliged to regrind them.

[13] Hutto Engineering Co., Detroit.

Anti-Freeze Solutions and Compounds

By H. K. Cummings[1]

Semi-Annual Meeting Paper *Illustrated with* Charts and Drawing

ABSTRACT

THE effectiveness and the advantages and disadvantages of various substances and compounds that are used or offered in the market for use in the radiators of automotive vehicles as anti-freeze materials are discussed. These include alcohols, glycerine, salts, oils, sugars, and a patented by-product of glycerine.

Properties affecting the suitability of a material or compound, or solutions of them with water to afford protection against freezing at atmospheric temperatures that are likely to be encountered are their heat capacity, freezing-point, boiling-point, specific gravity, viscosity, volatility, solubility, tendency to decompose at the boiling-point, inflammability, corrosive action upon metals, tendency to attack rubber, general availability, and price.

The freezing-points of solutions of different materials vary widely at the same concentrations, or proportions to water, and also with variation of their concentration. Determinations of the freezing-points as made at the Bureau of Standards are given in charts. The freezing-points also vary with the specific gravity, and determinations of these points are given. Large differences exist in the initial viscosity of water, oils and aqueous solutions of glycerine, glycol and honey, and in the rate of increase of viscosity with decrease in temperature. Curves of the determinations of such viscosity are shown.

Solutions of the salts of sodium, calcium and magnesium have much lower freezing-points than the sugar solutions and at much lower concentrations and afford protection at considerably lower minimum temperatures. Glycerine and ethylene glycol give protection at almost as low minimum temperature as magnesium chloride, which is the most efficient of the salts, but only at about double the concentration. Wood alcohol and denatured alcohol rank next in effectiveness, at concentrations of 50 and 70 per cent by volume, and resist freezing at a temperature of —40 deg. fahr.

Alcohol has several virtues as an anti-freeze material but boils at 172.4 deg. fahr., which results in its rapid loss by evaporation and limits the use of devices for maintaining high engine-temperature. Kerosene, on the contrary, has a high boiling-point that may result in serious overheating of the engine in mild weather. Other objections to its use are its odor and inflammability and its action upon rubber. Lubricating oil, glycerine and the solutions of sugar have high viscosity at low temperatures, which causes slow circulation of the cooling medium unless the passages in the cooling-system are ample.

Commercial distilled glycerine that is free from electrolytes and is practically neutral has no corrosive effect on metals and does not injure rubber; its evaporation is negligible and it can be recovered at the end of the cold season and used again. If alcohol that is lost by evaporation must be replaced four or five times in a season, glycerine at four times the price is less expensive even for one season. Glycerine is not recommended for use in cars having thermosiphon circulation, because of its high viscosity at low temperatures.

Ethylene glycol is a patented by-product of glycerine that sold in the winter of 1925 and 1926 at about the same price as glycerine. It gives more protection against freezing than either glycerine or denatured alcohol solutions of the same volume-per cent, is practically non-volatile, is no more corrosive than water, and is only slightly more viscous at low temperatures than denatured-alcohol solutions of equal concentrations.

In testing solutions for determination of their freezing-points, care must be taken to avoid the phenomenon of undercooling, that is, the tendency to resist freezing under some conditions at temperatures considerably below the maximum temperature at which crystals can begin to form. Apparatus used at the Bureau of Standards for making such determinations is illustrated and described. The present procedure and a proposed new method for testing the corrosive action of anti-freeze liquids are also described.

AS the Federal Specifications Board decided in April, 1926, that anti-freeze solutions for automobile and truck radiators were of sufficient importance to justify the adoption of standard purchase-specifications and referred the preparation of such specifications to a committee, the subject should be of considerable interest. Some of the factors that influence the choice of a radiator liquid, the advantages and disadvantages of various liquids that have been used in automotive cooling-systems, and the testing of commercial anti-freeze preparations will, therefore, be discussed in this paper.

Because circulation of the cooling medium is a matter of volumetric displacement, the relative efficiency of cooling liquids depends more directly upon their heat capacity per unit of volume than upon their heat capacity per unit of weight, that is, specific heat. The cooling-systems of most engines for automotive vehicles are designed to give just sufficient cooling when water is used as the radiator liquid. Water is reasonably satisfactory at temperatures above its freezing-point. Muddy water should not be put into the radiator and rain water should be used in preference to hard or alkali waters to avoid (*a*) the clogging of the radiator passages and (*b*) the deposition of scale that may impede the flow of heat from the engine cylinder to the water-jacket.

When the atmospheric temperature is likely to fall below 0 deg. cent. (32 deg. fahr.) water alone in the radiator is unsafe, as the expansion of the water by freezing may burst the radiator, injure the pump or crack the cylinders. To meet this situation, a liquid other than pure water must be used during cold weather. The liquid is usually a solution of one or more chemicals in water and may be vended as an "anti-freeze solution" ready-mixed for use or as an "anti-freeze compound" to be mixed with water in specified proportions according to the extent of protection that is sought.

Lubricating oil has sometimes been substituted for water in truck radiators as an emergency measure in cold weather, but the results may be unsatisfactory on account of the higher viscosity of the oil and its lower heat-capacity per unit volume. High viscosity requires larger passages for the flow of the liquid through the radiator, and low heat-capacity per unit volume requires more rapid circulation of the liquid. Success in cooling tractors with oil has been accomplished by taking account of these facts in designing the cooling-system. No

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study has been made at the Bureau of Standards of systems in which lubricating oil is used as the cooling medium, but a neutral oil that has a high flash-point and a low pour-point should be used.

Desirable Properties of Radiator Liquids

The first requirement of a liquid that is to replace water in a radiator in cold weather is that it shall not freeze, or at least shall not injure either the engine or the radiator by freezing, at the lowest temperature that may be encountered. To be satisfactory, however, such a liquid should (*a*) cause no damage to the cooling system by solvent action or corrosion and (*b*) circulate freely at the lowest operating-temperature. It is also desirable that it shall (*c*) boil without decomposing at about the boiling-point of pure water, (*d*) have a high heat-capacity per unit volume, (*e*) be readily obtainable at a reasonable price, and (*f*) be non-inflammable. A radiator liquid for automobile use should also be free from pronounced or objectionable odor.

Kerosene has been used with some success in cooling-systems that were designed for water although its heat capacity per unit of volume is less than one-half that of water. It is safe as regards freezing, circulates with comparative freedom at low temperatures and permits normal engine-temperatures in very cold weather without the use of radiator covers or shutters. However, in less severe weather the high boiling-point of kerosene may lead to serious over-heating of the engine. The odor and flammability of its vapor and its action upon rubber are objections to the use of kerosene.

How Concentration Affects Freezing-Point

The properties of aqueous solutions depend upon the concentration of the solutions. The variation in freezing-point with variation in percentage by weight for solutions of pure substances is shown in Fig. 1. The freezing-point of a solution is taken to be the maximum temperature at which crystals can begin to form when the solution is cooled slowly. The temperature at which the entire volume becomes solid may be considerably lower. The circles on the chart indicate the concentrations, or cryohydrates, that give maximum protection against freezing. Thus, although 14-per cent solutions of calcium chloride and of common salt with water have the same freezing-point, the minimum freezing-point that is obtainable with common salt is —21.3 deg. cent. (—6.3 deg. fahr.) whereas that with calcium chloride is —51.0 deg. cent. (—59.8 deg. fahr.).

It will be noted that solutions of glucose, or corn syrup, or of sucrose, which is cane sugar, appear to have minimum freezing-points above —10 deg. cent. (14 deg. fahr.) while the others shown on the chart will give protection at temperatures as low at least as —20 deg. cent. (—4 deg. fahr.). The cane-sugar cryohydrate is that reported by Guthrie[2] in 1876, but the solubility of cane sugar, which is 64.18 per cent at 0 deg. cent. (32 deg. fahr.) and 66.33 per cent at 15 deg. cent. (59 deg. fahr.), indicates that the minimum freezing-point should be nearer —15 deg. cent. (5 deg. fahr.) and at a concentration above 60 per cent by weight.

Among other solutions whose use has been proposed are those of magnesium sulphate, methanol, which is methyl or wood alcohol; isoamyl alcohol; and trimethylene glycol. Magnesium-sulphate solutions will not give protection below —3.9 deg. cent. (26.0 deg. fahr.), and isoamyl alcohol gives a minimum freezing-point in aqueous solution of —5.0 deg. cent. (31.1 deg. fahr.). The freezing-point curve for methanol-water solutions lies midway between the curves for calcium chloride and ethylene glycol; for example, a solution that contains 43 per cent by weight of methanol freezes at slightly below —40 deg. cent. (—40. deg. fahr.). The freezing-point curve for trimethylene glycol practically coincides with that for glycerine, of which this glycol is a by-product.

Fig. 2 shows the variation of the freezing-point with variation of the percentage by volume for solutions of commercial materials of strengths as indicated on the chart. The honey solution had a density of 1.403 grams per millimeter at 21.0 deg. cent. (69.8 deg. fahr.), and it is estimated to contain about 73 per cent of total sugar, so that the 67 and 75-per cent honey solutions are approximately equivalent to the 55 and 60-per cent invert-sugar solutions whose freezing-points are given in Fig. 1. The circles in Fig. 2 represent actual experimental determinations, all of which were made at the Bureau of Standards except the 59-per cent glycol value, which was determined by Curme and Young[3], and the last two glycerine values, which were determined by Lane[4].

Glycerine and Alcohol about Equally Effective

A freezing-point slightly lower than —40 deg. cent. (—40 deg. fahr.) was obtained at the Bureau of Standards with a 60-per cent glycerine solution made from a yellow glycerine that may have contained sufficient impurities to lower the freezing-point appreciably. Lane's value is accepted as probably correct pending redetermination of this point on a sample of known purity. The denatured alcohol that was used was 180 deg. proof. For alcohol of 188 deg. proof, or 94 per cent, the freezing-points are given in Table 1, from which it is evident that use of the stronger alcohol lowers the freezing-point of even the more concentrated solutions by only 1.0 or 2.0 deg. cent. (1.8 or 3.6 deg. fahr.). Alcohol that has been denatured according to formula No. 1: ethyl alcohol, 200 parts; methanol, 20 parts; and kerosene 1 part, will lower the freezing-point slightly more than denatured alcohol of the same proof strength that contains less methanol, but the difference is too small to be of importance. It will be noted that while, on a weight basis, alcohol up to 40 per cent lowers the freezing-point of water about twice as much as glycerine, equal volumes of denatured alcohol and 95-per cent glycerine are approximately equivalent in their effect on the freezing-point.

The specific heats of aqueous solutions, in general, decrease with increasing concentration at constant temperature and also decrease for a given concentration as the temperature is lowered. Denatured alcohol and methanol solutions are exceptions in that moderate quantities of alcohol, when added to water, actually increase its specific heat. Heat capacity per unit of volume is the product of specific heat and density. Since the

TABLE 1—FREEZING-POINTS OF DENATURED ALCOHOL SOLUTIONS

Alcohol, 188 Deg. Proof Per Cent by Volume	Freezing-Point Deg. Cent	Deg. Fahr.
10	— 3	27
20	— 7	19
30	—13	9
40	—20	— 4
50	—30	—22
60	—35	—31
70	—41	—42

[2] See *Philosophical Magazine*, vol. 2, p. 216.
[3] See *Industrial and Engineering Chemistry*, vol. 17, p. 924.
[4] See *Industrial and Engineering Chemistry*, vol. 17, p. 1117.

density of a given solution increases as the temperature is lowered, heat capacity per unit volume changes much less with the temperature than does specific heat. For solutions of greater density than pure water, such as salt or sugar solutions, the heat capacity per unit volume is greater than the specific heat, whereas for solutions of less density than that of water, such as alcohol-water solutions, the reverse is true. Consequently, all the aqueous solutions that are under consideration prove to be reasonably satisfactory as regards heat capacity. At room temperature the heat capacity per unit volume of a denatured-alcohol solution of 54 per cent by volume is 0.9 that of water and is approximately equal to the heat capacity of a 38-per cent ethylene-glycol solution or of a 56-per cent gylcerine solution.

Viscosity Increases with Concentration and Cold

The viscosity of most aqueous solutions increases with increasing concentration at constant temperature and also increases for a given concentration as the tempera-

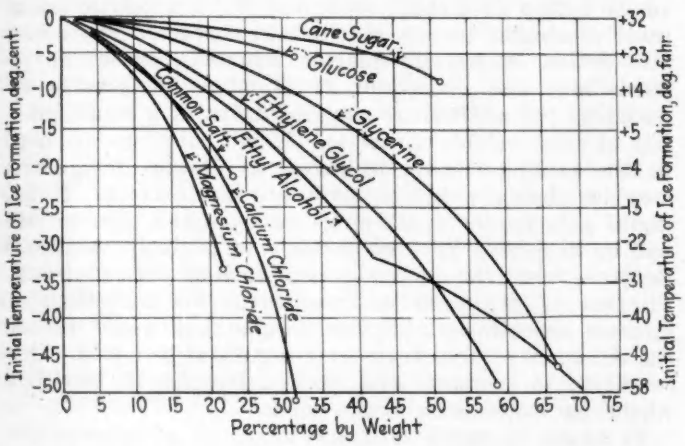

Fig. 1—Variation of Freezing-Point of Solutions of Pure Substances with Variation of Percentage by Weight
The Circles Indicate the Concentrations, or Densities, That Give Maximum Protection against Freezing. Although 14-Per Cent Solutions of Common Salt and of Calcium Chloride with Water Have the Same Freezing-Point, the Minimum Freezing-Point Obtainable with the Former Is —21.3 Deg. Cent. (—6.3 Deg. Fahr.). Whereas That Obtainable with Calcium Chloride Is —51.0 Deg. Cent. (—59.8 Deg. Fahr.). Glucose-Water and Cane Sugar-Water Solutions Have Minimum Freezing-Points above —10 Deg. Cent. (14 Deg. Fahr.), Whereas All the Others Will Give Protection at Temperatures Down to at Least —20 Deg. Cent. (—4 Deg. Fahr.)

ture is lowered. Fig. 3, which shows for comparison viscosity-temperature curves on four oils, illustrates the variation both with temperature and with concentration for honey, glycerine and glycol solutions. The concentrations were 50, 67 and 75 per cent by volume of the same commercial materials that were used for the freezing-point determinations.

The materials designated as Radiator Glycerine A and Radiator Glycerine B were two commercial products that were bought in the open market under trade names. Both were dilute yellow distilled-glycerines. The former contained about 60 per cent of glycerine by weight and the latter about 56 per cent. The increasing slopes of the curve marked Glycerine 67 Per Cent between 20 and —5 deg. cent. (68 and 23 deg. fahr.) is characteristic of the rapid increase in viscosity that usually occurs when a sufficiently low temperature is reached. The corresponding range for the 50-per cent glycerine solution presumably is 0 to —25 deg. cent. (32 to —13 deg. fahr.).

It will be noted that at 0 deg. cent. (32 deg. fahr.) the viscosity of the 50-per cent glycerine solution is 11 times the viscosity of pure water and that the viscosity of the 67-per cent glycerine solution is more than 40 times that of water. The 67-per cent glycol solution is found to

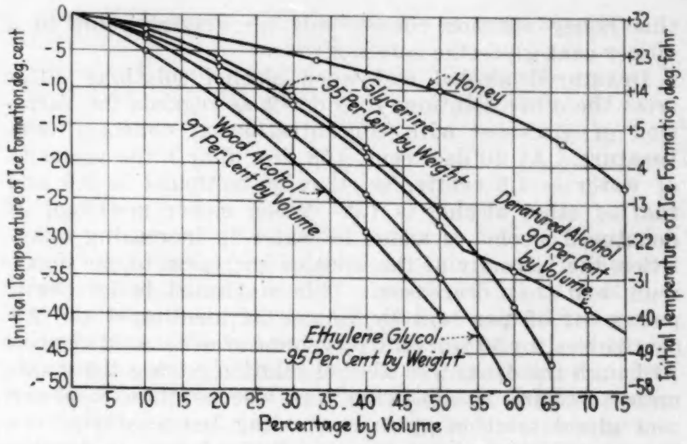

Fig. 2—Variation of Freezing-Point of Commercial Materials with Variation of Percentage by Volume
Although Alcohol, up to 40 Per Cent by Weight, Lowers the Freezing-Point of Water About Twice as Much as Glycerine, as Shown in Fig. 1, Equal Volumes of Denatured Alcohol and 95-Per Cent Glycerine Are Approximately Equivalent in Their Effect on the Freezing-Point, as Shown on Fig. 2

be distinctly less viscous than the 50-per cent glycerine solution at all temperatures and, while the 67-per cent honey solution has nearly the same viscosity as the 67-per cent glycerine solution, it should be recalled that

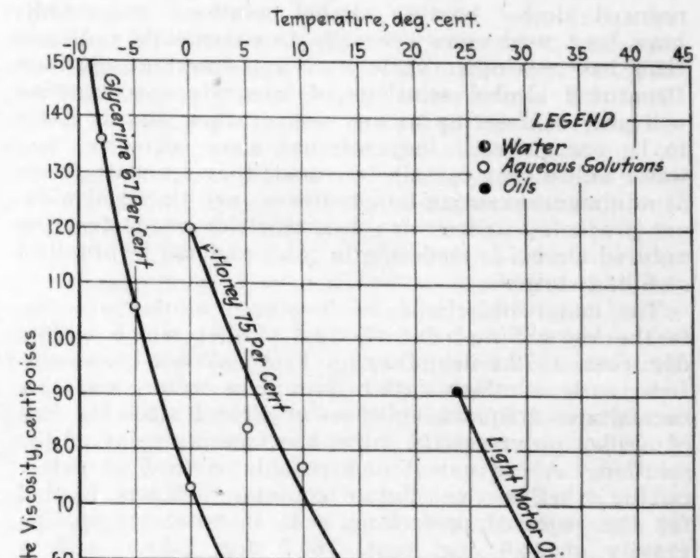

Fig. 3—Variation of Viscosity with Temperature Variation of Various Oils and of Solutions of Different Concentrations
The Increasing Slope of the Curve for 67-Per Cent Glycerine Solution Is Characteristic of the Rapid Increase in Viscosity That Usually Occurs When a Sufficiently Low Temperature Is Reached. Whereas the Viscosity of the 50-Per Cent Glycerine Solution at 0 Deg. Cent. (32 Deg. Fahr.) Is 11 Times That of Water, the Viscosity of the 67-Per Cent Glycerine Solution Is More Than 40 Times That of Water. High Viscosity Slows the Rate of Circulation of the Cooling Medium

this honey solution corresponds in freezing-point to a 40-per cent glycerine solution.

Denatured alcohol and wood alcohol solutions differ from the other solutions considered as regards the variation of viscosity with concentration at constant temperature. At 20 deg. cent. (68 deg. fahr.) the viscosity of water is 1.0 centipoise, that of methanol is 0.6 and that of ethyl alcohol is 1.2. When either methanol or denatured alcohol is added to water in increasing quantities, the viscosity of the solution increases to the maximum and then decreases. This maximum is 1.8 centipoises for 45 per cent by volume of menthanol and 2.8 centipoises for 50 per cent by volume of denatured alcohol. Although the denatured alcohol solution having the maximum viscosity is somewhat less viscous than a 50-per cent glycol solution at corresponding temperatures, the temperature-viscosity curve for this solution is similar to those of dilute glycerine and glycol solutions and it becomes very viscous at temperatures below —25 deg. cent. (—13 deg. fahr.). The light motor oil, of 219 Saybolt sec. at 100 deg. fahr., has an absolute viscosity of 90 centipoises at 24 deg. cent. (75 deg. fahr.), which is about that of olive oil.

Survey of Available Materials

Turning now to the relative merits of particular materials for radiator use, we naturally consider first denatured alcohol because alcohol solutions undoubtedly have been used more generally in automobile radiators than has any other variety of anti-freezing solutions. Denatured alcohol solutions of adequate concentration will prevent freezing at any temperature that is likely to be encountered; they are not more corrosive than water unless they contain free acid; they circulate freely at minimum operating-temperatures; and they boil without producing undesirable decomposition products. Denatured alcohol is moderate in price and can be obtained at filling stations.

The major objections to denatured alcohol are due to the low boiling-point of ethyl alcohol, which is 78.0 deg. cent. (172.4 deg. fahr.). First, alcohol evaporates from such solutions faster than does water, and this necessitates frequent additions of alcohol since the loss of alcohol progressively raises the freezing-point of the solution. A convenient and reliable method of determining whether the solution contains sufficient alcohol for the required protection is to measure its specific gravity at 15.6 deg. cent. (60.0 deg. fahr.) with a hydrometer. The curve at the left in Fig. 4 shows the relation between freezing-point and specific gravity for water solutions containing various concentrations of denatured alcohol. The other curves show the corresponding relation for solutions of wood alcohol and water, ethylene glycol and water and glycerine and water. Second, the boiling-points of alcohol-water solutions are distinctly lower than that of water, being 30 deg. fahr. lower for a 50-per cent solution, which fact limits the use of shutters and other devices that tend to maintain high engine-temperatures. Third, other objections to denatured-alcohol solutions are based on the unpleasant odor of certain denaturants, the possible flammability of the vapor under some circumstances and the marked solvent action of the alcohol on nitrocellulose finishes.

Methanol boils at 66.0 deg. cent. (150.8 deg. fahr.), hence its solutions have somewhat lower boiling-points than denatured alcohol solutions having equivalent freezing-points, therefore most of the objections to the use of denatured alcohol apply with even more force to the use of methanol. On the other hand, about 10 per cent less methanol than denatured alcohol is required for protection against freezing at any given temperature. Methanol for use in the radiator must be free from acid. The fumes from methanol, in addition to being unpleasant, are dangerous to health.

Salt Solutions Are Corrosive

Most of the other anti-freezing solutions are free from the difficulties that are incident to low boiling-point but many of them are less satisfactory than alcohol in other respects. Consider the salt solutions. Calcium-chloride solutions will give adequate protection against freezing, are not excessively viscous and boil at temperatures slightly above 100 deg. cent. (212 deg. fahr.), thereby permitting normal engine-temperatures in cold weather. Salt solutions can be used for an entire season without loss of effectiveness and require only the addition of water to replace that lost by evaporation. They should be very inexpensive.

The major objection to all salt solutions is their corrosive action on metals, especially the electrolytic action upon dissimilar metals that are in contact. The corrosive action of calcium-chloride solutions, except as regards zinc and aluminum, is found to be greatly reduced by the addition to such solutions of a small quantity of some soluble chromate. If salt solutions are used in the cooling-system, leakage may result in ignition troubles that are difficult to locate and correct. If the liquid gets on the spark-plugs or wiring, a film of salt will be deposited by evaporation and is likely to absorb moisture when the engine cools and cause a short-circuit. The use of salt solutions may favor the formation of mineral deposits on the jacket-walls that would reduce the efficiency of heat transfer from metal to liquid. This condition is common with cooling-systems in localities where the water is naturally hard.

To avoid corrosion troubles, solutions of non-electrolytes that have boiling-points higher than 100 deg. cent. (212 deg. fahr.) have been proposed. Among these are various sugars, glycerine and the glycols. The principal sugars whose use has been considered are glucose, honey and commercial invert-sugar. No concentration of glucose will with certainty prevent freezing at temperatures down to —5 deg. cent. (23 deg. fahr.), although 30-per cent glucose solutions may sometimes undercool to —10 deg. cent. (14 deg. fahr.) or lower without freezing. Similarly, water to which an equal volume of honey has been added may start to freeze at —10 deg. cent. (14 deg. fahr.) or the solution may undercool appreciably. The honey and invert-sugar solutions which give freezing-points below —15 deg. cent. (5 deg. fahr.) are exceedingly viscous and are supersaturated syrups that may granulate if held long enough at temperatures below 0 deg. cent. (32 deg. fahr.). The high viscosity alone makes them unsuitable for use in cars without pump circulation, as boiling-over is likely to occur and further concentration increases the danger of granulation. Sugar solutions, when in contact with very hot metal-surfaces, also tend to char and deposit carbon.

Neutral Glycerine Does Not Attack Rubber

Glycerine-water solutions have been objected to on the grounds of metallic corrosion and injury to rubber, but a distilled glycerine that is free from electrolytes does not seem to be subject to either objection. Glycerine solutions give adequate protection against freezing and boil without decomposition at temperatures slightly above the boiling-point of water. In the absence of leakage or overflowing, one charge of glycerine will last through the winter season without replacement, as the

evaporation of glycerine from the solutions used is negligible on account of the high boiling-point of glycerine. When glycerine solutions are prepared from the 95-per cent glycerine sold by druggists, it is preferable to mix the glycerine with the water before it is put into the radiator, as otherwise the concentrated glycerine tends to settle on account of its high density.

It is not necessary to use the United States Pharmacopoeia or chemically pure glycerine; a distilled glycerine that has been less highly refined is satisfactory provided it is free from electrolytes and is practically neutral. Many of the soap makers are putting radiator glycerines on the market under a variety of trade names. Most of these companies have agreed upon a uniform strength of 60 per cent of glycerine by weight for their products. The proportions recommended by the manufacturer of one brand of radiator glycerine, and which are equally applicable to all 60-per cent glycerine solutions, are given in Table 2, together with the specific gravities of the resulting solutions. While the percentages given in the table are considerably less than those shown in Fig. 4, experience seems to justify the use of the solutions recommended in the table, as the amount of ice crystals that are formed under these conditions is not sufficient to interfere seriously with circulation of the radiator liquid.

The only respect in which glycerine-water solutions seem to be inferior to alcohol-water solutions is in viscosity at low temperature. As was shown in Fig. 3, a 50-per cent glycerine solution is more than twice as viscous as the most viscous alcohol solution at 0 deg. cent. (32 deg. fahr.), hence it is evident that the more concentrated glycerine solutions will circulate less readily at very low temperatures than do alcohol solutions. In particular, the use of glycerine solutions of higher specific-gravity than 1.144, in cars having thermosiphon cooling-systems, at very low temperatures, is not recommended. Although glycerine is considerably more expensive, volume for volume, than alcohol, the first cost in the case of glycerine is the only expense, whereas the alcohol must be replaced at frequent intervals. For a moderately severe climate in which protection to —15 deg. cent. (5 deg. fahr.) is desired for 5 months in the year, an average car that is driven 100 miles per week is likely to require from four to five times as much alcohol as 95-per cent glycerine for the season. On this basis, chemically pure glycerine is less expensive per season than denatured alcohol at one-fourth the price per gallon. Furthermore, the glycerine can be drained out at the end of the season and saved for future use.

Glycerine-Alcohol and Ethylene-Glycol Solutions

Solutions of glycerine and alcohol in water are also used. The alcohol makes such a solution somewhat less viscous at low temperatures than a straight glycerine-water solution of equivalent freezing-point and the glycerine content assures that the solution will continue to give protection after the alcohol has evaporated. However, the use of such solutions is somewhat unsatisfactory because, after part of the alcohol has evaporated, it is not easy to determine from the specific gravity the freezing-point of the solution or how much alcohol and water must be added to restore the solution to its initial strength.

The claim often is made for glycerine-alcohol-water solutions that the presence of the glycerine reduces the rate at which the alcohol is lost by evaporation. Experiment fails to show any such effect of appreciable magnitude. When protection is required against temperatures of —35 deg. cent. (—31 deg. fahr.) or lower, it may be of advantage to add 10 per cent of alcohol to a 50-per cent glycerine-water solution instead of using 60 per cent of glycerine. Where adequate protection is given by 50 per cent or less of glycerine, the regular use of a glycerine-alcohol-water solution does not seem advantageous. On the other hand, some merit may be possessed by the suggestion that, instead of using throughout the season a glycerine-water solution of sufficient glycerine content to assure adequate protection at the lowest temperature that may occur, a less concentrated glycerine-water solution that will be adequate for the usual winter temperature may be used if, in exceptionally cold weather, alcohol is added for temporary additional protection.

TABLE 2—DIRECTIONS FOR USING 60-PER CENT RADIATOR-GLYCERINE

Parts by Volume Glycerine	Parts by Volume Water	Specific Gravity after Mixing	Minimum Temperature, Deg. Fahr.
1	1	1.080	+10
2	1	1.108	0
3	1	1.120	—10
4	1	1.130	—20
9	1	1.144	—30

Ethylene glycol is one of a group of chemicals whose use in aqueous solution as cooling mediums was patented 9 years ago[5]. This substance has become available in considerable quantities only recently. It is made indirectly from denatured alcohol and its manufacturers state that its retail price may be expected to decrease with increased production. It sold in the winter of 1925 and 1926 at about the same price as glycerine. Ethylene-glycol solutions give more protection against freezing than either glycerine or denatured alcohol solutions of the same volume-per cent. Like glycerine, ethylene glycol is practically non-volatile at engine operating-temperatures and its solutions are no more corrosive than water. Unlike glycerine, ethylene-glycol solutions are only slightly more viscous at low temperatures than denatured alcohol solutions of equal concentrations. Hence solutions of ethylene glycol seem to be superior to denatured alcohol solutions under all circumstances and, at least for very severe weather, to offer some advantages over distilled-glycerine solutions. Ethylene-glycol solutions can be used for an entire season without further addition of glycol and also can be drawn off at the end of the season and saved for use again. The specific gravity of ethylene glycol is not high enough to

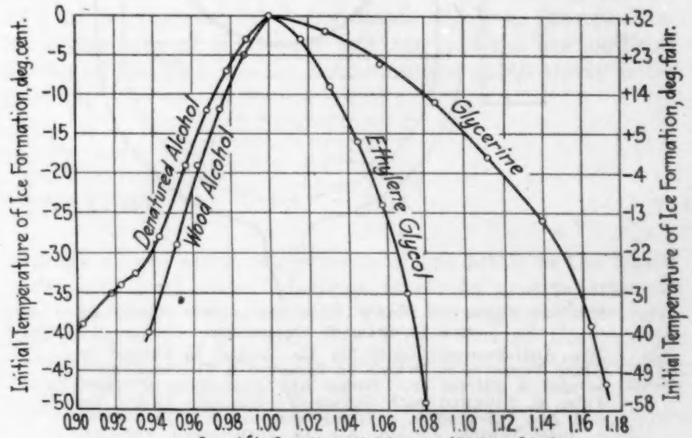

Fig. 4—Relation of Freezing-Point and Specific Gravity of Solutions of Various Densities

The Principal Objection to Alcohol Is Its Low Boiling-Point, Which Results in Rapid Evaporation and Limits the Use of Radiator Shutters and Other Devices for Maintaining High Engine-Temperatures

[5] See The Journal, November, 1921, p. 308.

necessitate mixing the glycol with water before it is put into the radiator.

How Anti-Freeze Preparations Are Tested

Automobilists in general are advised to use in the engine cooling-system only liquids that they have reason to believe are safe and effective as well as economical. The Bureau of Standards issues a letter-circular, Anti-Freeze Solutions for Automobile Radiators, for the information of the public on these points, but it is not the policy of the Bureau to publish test results or findings regarding specific trade-marked products. As numerous anti-freeze solutions and compounds are marketed under trade names that give no clue to their composition or probable value, a discussion of methods for the testing of commercial anti-freeze preparations may be of interest.

The freezing-point of a solution has been defined herein as the maximum temperature at which crystals can begin to form when the solution is cooled slowly. Even pure water may, under some circumstances, be cooled as much as 10 deg. below its freezing-point before it starts to freeze. This phenomenon of undercooling must, of course, be avoided in obtaining the freezing-point. Concentrated solutions of glycerine or alcohol as well as many sugar solutions undercool very persistently, but the undercooling of salt solutions usually can be prevented by adequate stirring. When undercooling cannot be prevented readily, a close approximation of the true freezing-point can be obtained by determining the melting-point of the crystals. For this determination the solution is cooled until crystals of ice appear and is then allowed to warm-up slowly in a double-walled test-tube that is provided with a thermometer or a thermocouple and a stirrer. The temperature at which the last crystals are observed to disappear or that at which the rate of warming increases will be the melting-point if the stirring is adequate and the rate of warming is not too rapid.

The freezing-point apparatus[6] shown in Fig. 5 has been used for many of the determinations that are reported in this paper. The liquid is placed in the pyrex-glass vessel *a*, which is provided with a thermocouple *b*, and a stirrer, *c*. Vessel *a* is placed within a pyrex tube, *d*, which is inserted in an unsilvered glass vacuum-walled vessel, *e*, into which liquid air can be introduced through the funnel *f*. The mouth of tube *d* is closed with cotton to prevent the entrance of moist air that would deposit frost upon it and hinder observations, and a slow stream of dry air is passed through *g* to prevent frost from forming within vessel *a*. The rate at which the liquid is cooled is controlled by adjusting the level of the liquid air in *e*. A small heating-coil in tube *d* below vessel *a* has been used to save time in cases where excessive cooling caused the liquid to freeze solid, since removing *a* from *d* would cause it to become covered with frost. Funnel *h* permits the introduction of a few drops of liquid air that, falling on the surface of the liquid in *a*, produce local cooling and usually cause crystallization to start if the freezing-point has been reached.

This apparatus has the advantage that the liquid, which is being tested, is under observation at all times and some idea of the relative viscosity of liquids at low temperatures can be obtained from the operation of the stirrer. The top of the stirrer *c* carries a weight, *i*, and is connected by a flexible wire to a rotating crank that is driven by a small electric motor. The function of the mechanism is to raise the weighted stirrer periodically and then allow it to fall under the influence of gravity. As the liquid becomes more viscous a degree of viscosity is reached that prevents the stirrer from touching the bottom of vessel *a* before the recurrence of the upward pull on the wire.

In view of the possibility of undercooling and the fact that all of the solutions that have been considered fill

[6] See Bureau of Standards Scientific Paper No. 520.

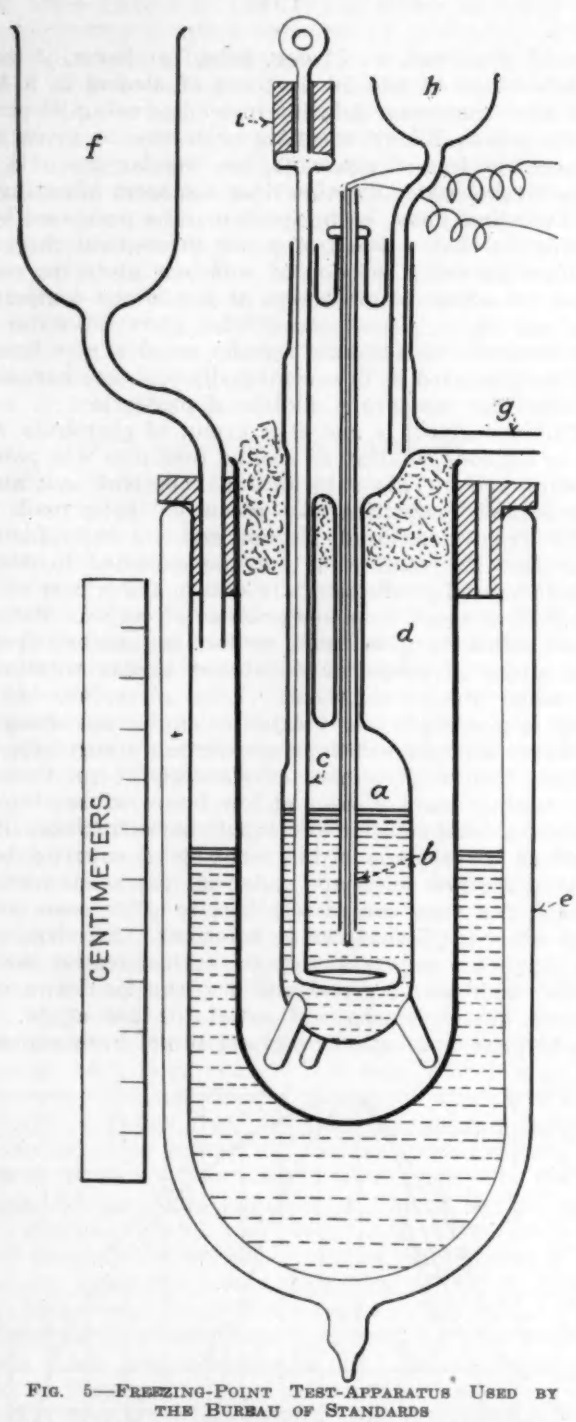

Fig. 5—Freezing-Point Test-Apparatus Used by the Bureau of Standards

The Anti-Freeze Liquid To Be Tested Is Placed in Glass Vessel *a* in Which Is Inserted a Thermocouple, *b*, and a Stirrer, *c*. These Are Placed in a Glass Tube, *d*, Plugged with Cotton To Exclude Moist Air and Are Inserted in a Glass Vacuum-Walled Vessel, *e*, into Which Liquid Air Is Introduced through Funnel *f*. A Slow Stream of Dry Air Is Passed through Tube *g* To Prevent the Formation of Frost. Funnel *h* Permits a Few Drops of Liquid Air To Fall upon the Surface of the Liquid in *a* To Start Crystallization When the Freezing-Point Has Been Reached. A Weight, *i*, at the Top of Stirrer *c* Is Connected by a Flexible Wire with a Crank Driven by a Small Electric Motor and Is Alternately Raised and Allowed To Fall by Gravity

more or less gradually with ice crystals in the form of slush as the temperature is lowered below the freezing-point, it is evident that Figs. 1, 2 and 4 allow a considerable factor of safety. Furthermore, solutions that contain less than 60 per cent of water by volume are unlikely to expand enough on freezing solid to damage the engine or the radiator. However, it seems desirable to use solutions of such concentration that ice crystals will not form at the lowest temperature to be encountered, since such crystals may clog narrow passages in the radiator and impair the circulation.

Thus far no measurements of absolute viscosity have been made on radiator liquids at temperatures below —10 deg. cent. (14 deg. fahr.) because of the great uncertainty as to what constitutes the limiting viscosity that is permissible with different types of radiator core. Evidently a very moderate viscosity can seriously retard the circulation when the driving force is only a small gravity-head, as in the thermosiphon system. It is believed that the relative suitability of different liquids as regards viscosity can be predicted safely from viscosity measurements at 0 deg. cent. (32 deg. fahr.) and at 20 deg. cent. (68 deg. fahr.).

Methods of Testing Corrosive Action

The seriousness of corrosion in automotive cooling-systems is a subject on which opinions vary rather widely. The American Society of Refrigerating Engineers is studying the problem of corrosion by calcium and magnesium brines, but the investigation has to deal mainly with the corrosion of iron and steel at low temperatures. With the advent of household refrigerating-plants, the action of brines upon copper, brass and solder has been found to be a source of considerable trouble. The higher temperatures that prevail in the automobile radiator lead one to anticipate that salt solutions which, by their electrolytic action, tend to remove solder from copper and brass would cause leakage at soldered radiator-joints within comparatively short periods of use.

The Bureau's present method of estimating the corrosiveness of radiator liquids is to tin with solder, for about half their length, strips of copper and of brass and suspend these in a beaker of the liquid, which is kept on a steam-bath continuously for a definite period of 15 or 30 days. At the end of the test period the appearance of the test-pieces is noted and each is weighed to determine its loss in weight. The average loss of the brass strips was 42 milligrams and that of the copper strips 65 milligrams. The average tinned surface per strip was approximately 11.0 sq. cm. (1.7 sq. in.).

Apparatus is being assembled for a new type of test in which test-pieces will be suspended in a tube through which heated radiator-solution is kept circulating. The test-pieces are to be of copper and brass about twice the thickness of the metal that is used in radiator cores. Some of the pieces are to be tinned like the present test-pieces and others will have holes drilled in them and plugged with solder. It is thought that this test will more closely simulate actual conditions in the radiator and may indicate the approximate time required for a given liquid to cause serious corrosion in a radiator.

TABLE 3—MATERIALS THAT PREVENT WATER FROM FREEZING AT 0 DEG. FAHR. AND THE QUANTITIES REQUIRED

Material	Quality, Per Cent	Quantity Per Gal. of Water, Qt.	Specific Gravity of Solution at 60 Deg. Fahr.	Boiling-Point of Solution, Deg. Fahr.	Viscosity, at 32 Deg. Fahr., Centipoises
Denatured Alcohol	90[a]	2.5	0.958	187	6.9
Methanol	97[a]	1.6	0.966	185	4.2
Honey		8.5	1.296	225	78.0
Chemically Pure Glycerine	95[b]	2.7	1.112	221	10.0
Radiator Glycerine	60[b]	8.5	1.112	221	10.0
Ethylene Glycol	95[b]	1.9	1.048	219	5.3
Common Salt	100 NaCl	2.2[c]	1.159	221.5	3.5
Magnesium Chloride	47 $MgCl_2$	4.4[c]	1.143	220.6	3.6
Calcium Chloride	75 $CaCl_2$	3.0[c]	1.178	220.8	3.1

[a] By volume.
[b] By weight.
[c] Lb.

Summation

Certain obvious disadvantages of various types of radiator liquid for use in present automobile and truck cooling-systems are:

Liquid	Objectionable Characteristics
Lubricating Oils	Viscosity and Low Heat-Capacity
Kerosene	Low Heat-Capacity
Denatured Alcohol	Low Boiling-Point
Methanol	Low Boiling-Point and Toxicity
Salt Solutions	Electrolytic Corrosion
Sugar Solutions	Viscosity
Glycerine Solutions	High Initial Cost
Glycol Solutions	High Initial Cost

In Table 3 are named nine commercial materials any one of which, if added to water in the proportion specified, will absolutely prevent freezing at temperatures as low as —18 deg. cent. (0 deg. fahr.). The specific gravity and boiling-point of each solution are given as well as its viscosity at 0 deg. cent. (32 deg. fahr.). The high viscosity of the honey solution and the low boiling-points of the two alcohol solutions are particularly noteworthy.

AMERICAN INCOME

THE aggregate income of the American people increased from $29,000,000,000 in 1909 to $61,000,000,000 in the last year of the war. Most of this huge increase, of course, was due merely to the war-time rise of prices. Correcting for this factor, we get an increase of nearly $9,000,000,000 in 9 years, or from $333 per capita in 1909 to $372 in 1918.

Regarding the distribution of income, farmers on the average secure about one-seventh of the total; in the highly organized large-scale industries employes receive some 70 per cent of the value product, while "management and capital" receive 30 per cent; only 1 per cent of the income-receivers in 1918 had more than $8,000 per year, and this 1 per cent received nearly 14 per cent of the total income.—National Bureau of Economic Research.

Automobile Headlighting Symposium

A HEADLIGHTING symposium, in which the various phases of the problem were discussed from the points of view of the Steering Committee, the manufacturers and the administrators of the headlighting laws, was a feature of the Annual Meeting. Three of the principal papers have already been printed in full in previous issues of THE JOURNAL, that by L. C. Porter and G. F. Prideaux on What Happens When an Automobile Headlight Is Out of Focus appearing in February, 1926; that by R. E. Carlson on the Headlighting Situation in the District of Columbia, in April, 1926; and that by W. D'A. Ryan on Automobile Head-Lamp Light-Characteristics and Improved Distribution, in the same issue. Other papers by H. M. Crane, R. N. Falge, E. C. Crittenden, W. L. Dill, Dr. C. H. Sharp, and J. H. Hunt are printed in full in this issue.

HEADLIGHTING

BY H. M. CRANE[1]

ABSTRACT

IF head-lamps were solely a question of comfort, an owner could demand what he wants, as he does with regard to color, the upholstering, the power of the engine, and other features of the car; but the universal opinion is that safety is paramount. Safety in driving at night requires plenty of light. The problem is to get plenty of light in the right place and not much in the wrong place.

Criticism is directed chiefly at glare, for the adjustments of the head-lamps of approaching cars are a measure of the enjoyment obtained from driving. The Steering Committee has undertaken merely to define good light-distribution rather than to learn how it can be obtained. Allowing different systems of distribution to be used, one when driving alone, the other when meeting an approaching vehicle, is an important but only a small part of the problem. Lowering the driver's seat and the increased action of the springs have rendered unsatisfactory the system previously in use which was adopted after careful research and was simple in operation. Instruction-books fail to call attention to the fact that in replacing a burned-out bulb the whole adjustment of the lamp is probably thrown out and must be remade. Even though an owner were expert enough to make the necessary adjustments, his frame of mind is usually such that he will not make them. To obtain comfort in driving, the construction and maintenance of head-lamps should be simplified. If the objectionable glare that is irritating, rather than that which is really dangerous scientifically, can be reduced to the minimum, a more powerful light can be directed where it is needed.

IN a meeting of car engineers and the Head-Lamp Steering Committee for the discussion of head-lamps, the question was brought up whether head-lamps should be considered from the point of view of safety or only of comfort. If head-lamps were solely a question of comfort, I would say that the car-owner could demand what he wanted, as he does with regard to the color of the car, the trimming used in upholstering the car or the power of the engine.

The universal opinion of those best acquainted with the facts, however, is that the head-lamp question is one of the very important questions of safety. I am glad that Mr. Carlson has preceded me because he has given definite proof[2] of the possible improvement in conditions obtainable in one city by the first effort at enforcement coupled with some popular education. Any enforcement officer will tell you the same story. The story is the same in that the emphasis is on the fact that, to get safety at night, we must have plenty of light. The difficulty has been to get plenty of light in the right place and not much in the wrong place.

The public is extremely resentful toward glaring headlights, as they are called, and the criticism the enforcement officer gets from the public concerns the glare. I think we all have the same feeling. We meet car after car on the road and are irritated. Purely from our own selfish point of view, something ought to be done. If we want more acceleration in our car, we know how to get it. If we wish to ride a little easier, we let a little air out of the tires. Unfortunately, however, no action that we selfishly take as to head-lighting is more than a partial cure.

In a congested territory, our individual action is only a drop in the bucket. If we meet 1000 cars, as is entirely possible in a night's driving, the adjustments of the head-lamps of that 1000 cars and the quality of their head-lights, not the kind of head-lamps we have on our own cars, are the measure of our enjoyment.

SAFETY AND COMFORT DEMAND ACTION

From the point of view of safety, duty requires us to do something; from the point of view of comfort our selfish interest makes it desirable to do something. With these two factors urging us on, we ought to get ahead.

We have formed a Steering Committee, under the auspices of the Illuminating Engineering Society and of this Society, to study the subject from the broad general point of view of what is good light-distribution. I wish to emphasize that point because this Committee cannot be expected to go into all the details of how desirable distribution is to be obtained. We must first decide what distribution is to be obtained. Many ingenious minds will then help us to the final answer.

The first action taken by the Committee, and I think a very important one, was the definite assertion that it had become desirable, due to experience obtained in 5 years' use of present types of equipment, to allow or require the driver of a car to use a different system of light distribution when driving alone on the road from that used when meeting an approaching vehicle. This opens an entirely new field of research and gives us a much freer hand to go ahead. I regret, however, that this is only a very small part of the problem. In some ways, it is the easiest part.

Some years ago, we put into effect a system of lighting based on limitations that had been worked out after a very complete research on the subject. Without any

[1] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

[2] See THE JOURNAL, April, 1926, p. 399.

question, when these limitations are closely adhered to, a fairly desirable result is obtained. At the time that the limitations were imposed on the industry, the result produced was very desirable.

I have called attention previously[3] to the change in conditions due to the lowering of the driver in the car and to the increased action of the springs which has made a system that originally worked rather simply almost impossible to work satisfactorily. This system, however, was based on some very accurate work; and I regret to say that we have kept from the owner of the car, with entire success, practically every bit of information regarding the details of adjustment and operation that are needed to get satisfactory results.

Bulb Changing Requires Refocusing and Reaiming

In the early days of regulation, the owner was told that if he put a certain lens on the car he would accomplish the desired purpose. Later on, he was informed that he should focus the head-lamp; still later, that he should point the head-lamp in a certain direction. I have conducted a slight investigation in a rather hurried manner to find out whether any car builder has yet divulged to the owner that, when he removes a burned-out bulb and replaces it with a new one, he will probably not only have to focus the new bulb but to repoint the lamp. I have in my hand about 12 or 15 volumes of the type that the owner seldom really reads. They are called instruction-books. I have not found in any of them a statement calling attention to the fact that, in doing what is frequently an ordinary piece of replacement work, the whole adjustment of the head-lamp is probably thrown out and must be made again.

One of the finest pieces of work done toward breaking down this system of secrecy is Mr. Porter's paper.[4] I will gladly admit that, together with other car-owners, I was entirely in the dark as to the enormous variations produced in the pointing of the head-lamp by variations in the position of the filament.

One way in which we have tended to deceive the owner is by putting a screw on the head-lamp and calling it a focusing device. The focus of a parabolic reflector is a definite point located in three planes. The only screw that is put on for focusing will, if not rusted, move the bulb along only a single line.

Irritation of Driver a Cause of Poor Adjustment

Granting that an owner knows enough to go through all the necessary motions of readjustment after the placing of the bulb, I still hold that it is too much to expect that, in the irritated frame of mind he reaches during the time of replacing, he will do anything of the kind. We attempt to make the lamp water-tight and dustproof for obvious reasons, for protecting the 1/20 of a cent's worth of silver around the reflector, and, by the time the owner has broken his way into the lamp and replaced the bulb, he wants to be on his way.

If we were not attempting a very accurate direction of a very high-powered beam, we need not be so careful about many of the items involved in lamp construction and lamp adjustment. I believe, however, that it is entirely possible to do what we want to do in very much less time than has been required to date.

Mr. Porter very justly has said[5] that if we can give the owner a better lamp than he has been used to, he will pay for it; and I am sure that the owner who uses a lamp to any considerable extent will gladly do so. We must convince him, however, that a lamp is really worth some money.

The lamp in the instruction-book is not the lamp of actual use. The instruction-book, in making suggestions regarding pointing, says that a line should be drawn on the wall at the height of the lamp center, and that the beam should be adjusted to be below that point. In Massachusetts and New York, the nearest approach to that horizontal line that is allowed is 5 in. in the case of long cars and from 7 to 9 in. in other cars; and a very different result is obtained.

Simplicity an Important Feature

I hope to see as a result of this discussion, first, a great simplification of the method of head-lamp construction and maintenance. So long as we depend on the other driver for our comfort on the road, we must make it easy for him to be good to us. I am in favor of doing so. If we can produce a head-lamp in which he can change a bulb as easily as he can change one in his home, and can produce a lamp in which a single adjustment will cause correct pointing, we shall have gained much. If, by careful research, we can reduce to the minimum, not the glare that is really dangerous scientifically, but the objectionable glare that is irritating, we shall be able to use a more powerful direct light where it is needed. I am certain that we can do all these things, if we will but concentrate all our forces and keep at it.

In working out the light distribution of the original specifications of the Illuminating Engineering Society and of this Society, certain testing equipment was used. A car was equipped with a sufficient number of lamps of ordinary construction, with the necessary rheostats and control-switches to allow varying the light at the will of the driver and the observer while the car was in use. It is now desired to make a similar series of tests, based on controllable equipment and controllable illumination.

FUNDAMENTAL PRINCIPLES OF HEADLIGHTING AND GLARE

BY E. C. CRITTENDEN[6]

ABSTRACT

GENERAL statements about desirable lighting effects are easy to make. Laws, however, while specifying results, should not try to determine how the results are to be obtained. Specifying that a bridge must carry a stated load is simple, but it takes a trained man to determine how much steel shall be used and how it shall be fabricated to carry that load.

The purpose of lighting is that we may see, but vision depends upon the behavior of the eyes, an organ of changing sensitivity. Although the quantity of light admitted to the retina can be regulated in the ratio of about 10 to 1 by the adjustability of the aperture of the pupil, which acts in a manner similar to that of the diaphragm of a camera, the sensitivity of the eye as a whole can change by a factor of at least

[3] See The Journal, December, 1925, p. 560.
[4] See The Journal, February, 1926, p. 222.
[5] See The Journal, February, 1926, p. 231.
[6] Electrical division, Bureau of Standards, City of Washington.

1,000,000. The eye can see when the general illumination changes in the ratio of about 1 to 100,000. Time for adjustment, however, must be allowed and no such excessive range can be allowed in the field of vision at the same time.

The fundamentals of lighting and vision are said to be (*a*) the light must fall on the thing to be seen, (*b*) the light must be reflected into the eye and (*c*) the difference in the quantity of light received from different parts of the field must not be excessively great. Back of the variable eye, a still more erratic mental operation takes place, for the eye does not see until the mind responds to the prick that the eye nerves give it. Most seeing is really guessing, the accuracy of which depends on several variables, such as the time-element, size of the object, its contrast with the background and between the parts, and the presence of other disturbing objects in the field of vision. The only reasonable way to find out how much light is needed for a complex operation is to take the consensus of opinion of many persons.

The statement is made that, for satisfactory vision, the illumination should not be much less than 1 ft-candle, the nearer foreground should not be illuminated to a much higher degree than objects at a distance and the candlepower should be low at the lower angles and should increase rapidly as the horizontal is approached. Vision is best when all parts of the field are approximately of the same degree of brightness. The interference increases as the difference in brightness is increased. If the difference is as much as 100 to 1, the effect is very disturbing. A head-lamp cannot give the desired illumination unless it has sufficient candlepower in the direction in which it is needed, but it must not show its intensity in the direction of other drivers. Complying with these conditions calls for optical apparatus of good design and accurate construction and a support that will keep it rigidly aligned.

IT is easy to talk in general terms about lighting effects. So, we have the common statement in many laws that enough light must be provided to make visible a substantial object, like a man, at a distance of 200 ft. and that no glaring or dazzling rays shall be thrown above a specified height at a distance of 75 ft. from the car. I am not finding fault with these requirements. They are all right as a general statement of the results we want to get, and they seem to satisfy the legislators and the lawyers who wish to put into the law some requirements that they think are definite. In fact, laws should specify results, but they should not try to tell how those results are to be obtained.

As engineers, you know that it is one thing to tell what you want to do, and a very different matter to tell exactly how you can accomplish it. Anyone can specify that a bridge must be made to carry a stated load, but it takes a trained man to say how much steel shall be used and how it shall be fabricated to carry that load. This job of figuring things out in exact terms is the engineer's business and, naturally, he learns to think in exact terms. So, it is not surprising that some engineers take up the lighting problem with the idea that somebody ought to be able to say just how much light is needed to make a thing visible and just what brightness makes a light glaring. But those who expect this exact data are due for a disappointment.

First of all, the purpose of lighting is that we may see. We see with our eyes. The foundation of all experiments on lighting must therefore be the behavior of our eyes.

Fundamental Principles of Lighting and Vision

The fundamental principles of lighting and vision can be stated very simply in qualitative terms, but to give exact and correct quantitative values of the amount of light needed for vision is practically impossible, because the eye is an organ of changing sensitivity. The eye may be compared with a camera, if the comparison is not carried too far. To take a satisfactory photograph, we know that the field to be pictured must not show excessive contrast and that it must throw a proper volume of light into the camera. We can adjust this volume of light to some extent by a diaphragm in front of the lens. The eye has a similar arrangement in its pupil, which is adjustable in size but has the further complication that the sensitive film or retina automatically adjusts its sensitivity over a range that is very much greater than the change in the aperture of the pupil.

I wish to emphasize this, because to think of the variation of the pupil as the chief adjustment of the eye when exposed to light is entirely wrong. The change in area of the pupil is something like 10 to 1, whereas the sensitivity of the eye as a whole can change by a factor of at least 1,000,000. The ability of the eye to adapt itself to different levels of illumination is so great that we can see to get about with a fair degree of convenience when the general illumination changes in the ratio of 1 to 100,000; but time must be allowed for this adjustment of the eye, and no such excessive range can be allowed in the field of vision at the same time, since adaptation of the eye takes place as a whole and the eye cannot at the same time be adjusted for both bright and dim lights.

The fundamentals of lighting and vision are then: (*a*) the light must fall on the thing to be seen, (*b*) the light must be reflected into the eye and (*c*) the difference in the quantity of light received from different parts of the field must not be excessively great. Obviously the light received by the eye is what counts, and this necessarily depends on the reflecting properties of the thing looked at as much as on the quantity of light thrown upon it. In ordinary lighting, this factor is taken into account by providing more light when work must be done on dark-colored materials; but, in headlighting, differences of reflection from road surfaces and other objects are lumped together as one of the many variables that must be roughly averaged in reaching a conclusion as to what conditions may be most satisfactory.

Vision Depends on an Erratic Mental Operation

But, if we assume some definite conditions, is it not possible to find an exact answer to the question: How much light is necessary to see a thing? The answer is, "No, not an exact answer"; for, even back of the variable eye, we have a still more erratic mental operation to deal with. We do not "see" a thing until the mind has responded to the prick that the eye nerves give it; and we are most easily deceived, for often we "see" what is not present and fail to see what is actually before us. Much of our seeing is really guessing, more or less accurately done. It is therefore necessary to use statistical methods, to change conditions and to note when a specified percentage of the guesses come right.

Furthermore, the time-element comes in; for, when the illumination is low enough so that increasing or decreasing it has much effect, we gain in speed of perception as well as in certainty by having more light. The light required to see an object within a specified short time, therefore, may be much greater than that which would suffice to make it visible on careful examination. That the perception of an object depends on many other variables, such as its own size, its contrast with the background and between its parts and the presence of other disturbing objects in the field of vision is also obvious.

Visibility Determined by Consensus of Opinion

In brief, without drawing out this tale of difficulties to greater length, the conclusion can be stated that the only reasonable way to find out how much light is needed for a complex operation is to try that operation with different quantities and experiment until we find out what seems to be satisfactory. This has been done at considerable length by various experimenters in the field of headlighting; but I shall not try to review their results. That no specific figures can be considered as having any very scientific basis will be evident; certain minimum and maximum values have been arrived at as representing, in the opinion of many persons, limits beyond which no headlight should go; some other figures giving a consensus of opinion as to a light distribution that would be satisfactory to most drivers have been promulgated, as, for example, those issued by the Lighting Division of the Standards Committee.

For really satisfactory vision, the illumination should not be much below 1 ft.-candle, although a fraction of this quantity may suffice when quick perception is not necessary. This would mean for example that, if an object at a distance of 100 ft. is to be well illuminated, the candlepower of the source of light must be about 10,000 and, of course, for the same illumination at 200 ft., the candlepower would have to be 40,000. Good vision of objects at these distances would also require that the nearer foreground should not be illuminated to a much higher degree. Consequently, if we could use head-lamps in which the candlepower were low at the lower angles and increased rather rapidly as the horizontal is approached, the general distribution of light on the landscape ahead would be most satisfactory for the vision of a driver behind the head-lamps. To have an illumination of similar value thrown on the whole landscape ahead and to the sides of the car would be most agreeable. However, two considerations make this impracticable. One is that the quantity of light which can be provided is limited; the other is that we must consider drivers facing in the opposite direction.

Glare Increases with Difference of Brightness

This introduction of another driver brings in the question of "glare." Glare, again, is a thing that can hardly be stated in quantitative terms. The simple fact is that we can see best when the whole field of view is approximately of the same degree of brightness. If any part of it is much brighter than the thing we wish to see, our perception of that thing is more or less interfered with. This interference naturally increases as the difference in brightness is increased, but it is less when the disturbing bright object is farther from the line of vision. No sharp line can be drawn at which one can say that a light in the field of vision becomes glaring. If the brightness of such a light is gradually increased, its detrimental effect grows gradually greater. When the disturbing light is near the center of the field of vision and is anything like 100 times as bright as the thing we wish to see, it becomes very disturbing. Although this ratio of 100 to 1 may seem to give a large margin, it is in fact so small as to be very troublesome in artificial lighting of every kind. Even in interior lighting, where conditions are relatively favorable, to avoid troublesome glare is by no means easy. In street lighting, the difficulties are much greater; and we are far from having a satisfactory solution for them.

When we come to lighting by automobile head-lamps, the conditions are about as bad as could possibly be devised. An illumination of 1 ft.-candle has been suggested above as being desirable. A white object under such an illumination, if considered as a source of light itself, has a brightness of about 1/4 cp. per sq. ft. A head-lamp of ordinary size giving 10,000 cp. will have a brightness around 25,000 cp. per sq. ft.; that is, it will be 100,000 times as bright as the white object and often 500,000 times as bright as the general landscape lighted by a pair of similar head-lamps at a distance of from 100 to 200 ft. Obviously, therefore, if head-lamps of such candlepower are to be permitted they must be directed so as not to show this intensity in the direction of other drivers. That the head-lamp cannot give the illumination desired unless it has these candlepowers in the direction in which the light is needed is equally obvious, however. The unescapable question is, then, whether head-lamps can be provided that will light the road without throwing this excessive quantity of light into the eyes of other drivers.

Control of Light Demands Accurate Apparatus

Of course, various answers can be given to this question, and we are at liberty to choose between several solutions of the difficulty. We cannot, however, escape the fact that, to have light on the road, we must have head-lamps showing a corresponding candlepower in the direction in which that light is to be furnished. Other speakers will undoubtedly have suggestions as to the choice of method to be followed in meeting this difficulty. The one point I wish to emphasize is that the unavoidable condition to be met includes the problem of furnishing a large quantity of light on the road and of projecting a small intensity at a small angle above the road, at least at times when other cars are approaching, which, for most of us nowadays, means most of the time. This necessarily calls for optical apparatus of good design and of accurate construction and a mechanical support for this apparatus that can be depended upon to keep it correctly aligned. An example that I have used before may be suggestive here. We would not expect a William Tell to shoot the apple with a shot-gun. No more can we expect to shoot light accurately where we want it without having precise and correctly aimed devices.

The responsibility for furnishing these devices rests with the builders of automobiles. The responsibility for putting them in good condition rests with the dealer and the distributor, but the responsibility for keeping them in good condition must be divided between the service-station and the individual driver; and the whole chain must work together, or we shall not have good lighting conditions.

If you go out to study lights, do not judge them by looking at them. Judge them by looking at the road where you wish to go; and if you have anything to do with the education of drivers, try to get them to do the same thing: get their own lights in reasonable condition; watch the road and not the other man's light.

HEADLIGHTING FROM THE ADMINISTRATOR'S POINT OF VIEW

BY W. L. DILL[1]

ABSTRACT

FROM the point of view of administrators, more common sense and less science should be embodied in headlighting regulations. The motoring public in case of accident finds a ready alibi in the statement that the driver was blinded by glaring head-lamps. Drivers buy cars equipped with approved head-lamps, assume that they are within the law and make no effort to find out. In New Jersey, an educational campaign of lectures illustrated with stereopticon views stimulated little interest on the part of the public. Builders use the cheapest head-lamps that will comply with the requirements, and these are responsible for most of the evils. One company that produces a large number of cars annually equipped them in 1924 with head-lamps 88 per cent of which were out of adjustment. Customers should be impressed with the fact that to direct the light properly is as important as to know how to manipulate the brakes and gears. The suggestion is made that the industry should regulate itself rather than have legislative enactments forced upon it. In the author's opinion, enforcement of the State laws is fruitless unless the equipment is sufficiently well constructed to comply with the law respecting head-lamps, without requiring constant attention on the part of the driver.

I COME not as an engineer but as a layman, an administrator of the law who has been close to this problem for 11 years, and speak for the first Commonwealth of the Union to enact a head-lamp law. Mindful of my connection with the Eastern Conference of Motor-Vehicle Administrators, who have banded together to assist in the enactment of a uniform law, I communicated with Robbins B. Stoeckel, motor-vehicle commissioner of Connecticut, and told him of my plans. With your indulgence I will read his reply. He said:

> I addressed this same conference some time ago. So far as I am concerned, I would be delighted to have you speak for me on any subject whatever, either individually or as President of the Conference. I think, however, that if you are planning to get the commercial standpoint out of these fellows you will not make much headway. I am perfectly willing that you should try, and you have my blessing.

While sitting in the Hoover Committee with the Society of Automotive Engineers Headlight Committee, I have had this thought on the subject of head-lights, which has grown out of the conferences. It appears to me that we ought to get more common sense and less science into the proposition of lighting, and I am working now on what I know you will feel to be worthwhile, namely, to get some program that the Conference can adopt, which, more or less through the fact that the Conference members are enforcing the law, will impose this common-sense feature upon manufacturers and engineers.

Last week five prominent citizens of Perth Amboy, N. J., left my office. They had motored to Trenton for the purpose of seeing the Prosecutor of Pleas of Middlesex County sworn into office. They all were officials of the city. If you are familiar with the stretch of road that connects New Brunswick and Metuchen, you will recall that it is a beautiful highway, well illuminated and with few turns. I was shocked when arriving at my office on Tuesday morning to learn that three of these men had been killed on their way home. A hurried examination on the part of one of my inspectors indicated to my satisfaction, and I say this most charitably, that the accident was due, first, to preoccupation of mind on the part of the driver and, second, to speed.

GLARE A READY ALIBI

Let us see what the papers in chronicling the disaster said. I take this from the *New York Times:*

> The driver of the car when taken into custody said that he had been blinded by the head-lamps of an approaching machine and was unable to see the truck into which he crashed a moment later.

That is the situation. The motoring public today, conscious of the inability of you scientists to solve the problem, seek as a ready alibi, when involved in an accident, the fact that they have been blinded by the head-lamps of an approaching car. And you talk about education! Let me say that the most procrastinating lot of individuals are those who drive motor vehicles. They like to follow the line of least resistance. They buy cars equipped with lamps approved by the authorities of the State, proceed on the assumption that they are within the law and make no attempt to ascertain whether they are or not.

That we might drive home forcefully the seriousness of this situation, we carried stereopticons up and down the State of New Jersey, broadcasting our coming with all the publicity possible. The outfit consisted of 12 lamps, mounted on tripods, with screens and accompanied by a splendid lecturer. We invited the motoring public to come and ascertain just how their lamps might be placed in focus. In a city having a population of 500,000, during a 3-night stand, the greatest number of persons at any show was 227. At Atlantic City we played to 74. Admission was free.

Much of the fault, I believe, is due to the builder, because of his desire to produce a car as cheaply as possible, so that he can compete successfully with his competitors. If a certain device conforms to the specifications adopted by the Society, the manufacturer who can sell it cheapest eventually will get the business. In other words, cheaply constructed head-lamps are, in my opinion, responsible for most of the evils arising from glaring lights.

IMPROVED CONSTRUCTION NECESSARY

Mr. Porter covered the situation admirably in his paper[2]:

> This is not only the bulb manufacturers' problem—but also the problem of the manufacturers of lamps in producing sockets, focusing devices and reflectors that will "stay put" within 2/64 in.

Imagine getting a pair of successful lenses that can be purchased on the market today for from $0.15 to $0.18 apiece and a pair of complete head-lamps for $1.90! It cannot be done if the public, which knows nothing about illumination, is expected to answer to the authorities because the lamps are not in focus.

A very illuminating brief was recently submitted to the Hoover Conference by manufacturers of lamps and accessories. I believe it would be well if the Steering

[1] Motor vehicle commissioner, State of New Jersey, Trenton, N. J.

[2] See THE JOURNAL, February, 1926, p. 231.

Committee referred to by Mr. Crane should analyze that report and perhaps collaborate with the Hoover Conference. I feel that not only the Hoover Conference but the Steering Committee should consult representatives of the Eastern Conference of Motor-Vehicle Administrators and representatives of the Bureau of Standards, for whom I have the most wholesome regard. In passing, I would like to pay tribute to the splendid work that has been done by the Illuminating Engineering Society. If we have accomplished anything at all, it has been due to the unselfish way in which they have worked with us.

The problem is serious. Administrators can no longer satisfy the public by stating that the lamps complained of comply with the specifications. There must be something more than that or they will constantly invite a charge of laxity.

One of the largest builders of automobiles, whose plant is situated near the State-line that divides New York and New Jersey and who has occasion to use the roads for delivering thousands of machines annually, sent out a number of machines in 1924, 88 per cent of the lamps of which showed, upon inspection, that they had not been adjusted.

Properly Directed Lights as Essential as Brakes

I believe that not only has an attempt been made to get too cheap lamps, but little or no attention has been paid to sending automobiles out properly equipped and to impressing upon those who come into close contact with the customer—the field men—the necessity for impressing upon the purchaser that, although sufficient light should be available, to direct the light where it properly belongs is just as essential as to know how to manipulate his brakes and gears.

So, speaking for New Jersey, I think I can safely say for the Eastern Conference, the membership of which registers 30 per cent of all the automobiles in the United States, that the crux of this problem is covered in the following statement on headlights that has been sent to me:

> Coordinated efforts in the solution of the head-lamp problem would tend toward a proper condition, namely, that the industry regulate itself rather than let a bad condition persist until law enactments are forced upon innocent persons

because surely, as the devices change and the commercial aspect becomes paramount and the administrators recognize their inability to cope with the situation, their first act will be to rush to the legislatures and ask for a remedy, until so many laws have been enacted on the statute books that the possibility of getting uniform statutes will be well-nigh impossible.

I heartily concur in the resolution, passed at a recent meeting, concerning the Joint Committee of the Illuminating Engineering Society and this Society, and giving a program of headlighting research. This Joint Committee is to determine what the program shall be, how it shall be carried out, by whom and where. I believe the Committee ought to include among its membership some persons from the Bureau of Standards and the Motor-Vehicle Administrators.

In closing, I would like to make a most positive affirmative answer to the query:

> Except as a means of compelling motorists to accept education on the subject, is not the enforcement of State laws fruitless unless the equipment is sufficiently well constructed to comply with the law respecting head-lamps, without requiring constant attention on the part of the driver?

IMPROVEMENTS IN HEAD-LAMPS

BY R. N. FALGE[9]

ABSTRACT

OBSERVING that the art of headlighting has already advanced beyond the conditions upon which recently published data are based, the author calls attention to several principles of design already pointed out in a previous discussion by him which render the beam pattern less sensitive to commercial variations in the optical elements of the head-lamp, chiefly that of forming the upper part of the beam from the middle transverse section of the unit and tilting the light from the upper and the lower sections downward. Comparative tables are submitted of typical data from Mr. Porter's paper and of those on a compensated device. The opinion is vouchsafed that, if focusing could be eliminated and aiming were the only operation in adjustment, cooperation between the industry, the trade and the motorist would be easy to obtain. Attention is called to data showing the possibility of eliminating focusing when equipments are suitably designed and accurately made. Filaments of well-made incandescent lamps are said to be well within the 3/64 in. positioning tolerance of the S.A.E. Standard. So great a variation as 5/64 in. is no longer contemplated, whereas the total variation in the device and within the bulb may safely be somewhat greater than 2/64 in.

[9] M.S.A.E.—Engineering department, in charge of automotive lighting, National Lamp Works, Cleveland.

TABLE 1—EFFECT OF FILAMENT VARIATIONS AHEAD AND BACK OF THE FOCUS ON (*a*) A TYPICAL LENS INCLUDED BY MR. PORTER AND ON (*b*) A COMPENSATED DEVICE

	Light-Source Position								
	At Focus		4/64 In. Behind Focus			4/64 In. Ahead of Focus			
S.A.E. Test-Point	Device No. 1 Aimed	Device No. 2 Aimed	Device No. 1 Not Reamed	Device No. 1 Reamed	Device No. 2 Not Reamed	Device No. 1 Not Reamed	Device No. 1 Reamed	Device No. 2 Not Reamed	S.A.E. Recommended Practice
D	786	460	4,750	788	575	2,374		750	0— 800
C	874	870	4,874	788	830	2,624	No	1,000	800—2,400
A	4,374	5,000	10,750	3,124	6,000	7,500	data	5,900	2,000—6,000
B	16,250	31,000	15,624	8,250	26,000	17,500	given	29,000	25,000+
P_l	29,360	10,800	15,000	11,874	17,300	26,250	by	11,200	10,000+
P_r	30,874	9,100	15,624	11,124	15,000	27,800	Mr.	10,600	10,000+
Q_l	8,124	7,300	8,750	7,750	5,200	7,500	Porter	5,550	4,000—8,000
Q_r	8,750	8,800	7,750	9,000	3,500	8,000		4,400	4,000—8,000

TABLE 2—EFFECT OF FILAMENT VARIATIONS ABOVE AND BELOW THE FOCUS ON (*a*) A TYPICAL LENS INCLUDED BY MR. PORTER AND ON (*b*) A COMPENSATED DEVICE

	Light-Source Position									
	At Focus		3/64 In. Below Focus		5/64 In. Below Focus		3/64 In. Above Focus		5/64 In Above Focus	
S.A.E. Test-Point	Device No. 1 Aimed	Device No. 2 Aimed	Device No. 1 Reaimed	Device No. 2 Reaimed	Device No. 1 Reaimed	Device No. 2 Reaimed	Device No. 1 Reaimed	Device No. 2 Reaimed	Device No. 1 Reaimed	Device No. 2 Reaimed
D	786	500	788	600	798	600		700		600
C	874	1,000	1,012	1,200	912	1,400	No	1,400	No	1,300
A	4,374	6,000	4,250	6,000	3,374	6,000	data	6,000	data	5,000
B	16,250	27,700	21,600	25,000	13,000	21,400	given	24,400	given	15,400
P_l	29,360	13,950	34,000	14,400	20,000	15,700	by	12,900	by	11,000
P_r	30,874	15,100	30,874	16,200	18,550	15,700	Mr.	11,700	Mr.	11,600
Q_l	8,124	5,000	7,500	3,800	11,750	3,800	Porter	5,100	Porter	5,400
Q_r	8,750	5,000	10,750	4,200	13,124	4,500		5,600		5,800

A COMMENT that strikes me as being pertinent with reference to Mr. Porter's interesting and well-arranged data[10] is that they apply to devices which do not include representatives of the modern trend of head-light design. In other words, the art has already advanced well beyond the conditions he suggests.

In another discussion[11], I have pointed out several principles of design, incorporated in a variety of modern equipments, which render the beam pattern far less sensitive to commercial variations in the optical elements of the head-lamp. The chief one is that of forming the upper part of the beam from the middle transverse section of the unit and tilting the light from the upper and the lower sections downward. The value of this compensating feature in minimizing the effects of variations ahead of and back of focus is indicated by a comparison of typical data from Mr. Porter's Tables 1, 2, 3, and 8 with the data on a compensated device, as shown in Table 1 herewith. The difference is most pronounced. Sidewise variations, as given in Mr. Porter's Table 6, are relatively unimportant in practice and hence are not included here.

It appears to be the general opinion of those who have studied the servicing of headlighting that, if focusing could be eliminated so that aiming would be the sole operation in adjustment, to bring about the cooperation of the industry, the trade, and the motorist in keeping head-lamps adjusted generally would become relatively easy. Especially is this true with the mountings now used by many car builders that make aiming the lamps a very simple matter. The data of Table 1 point clearly toward the possibility of eliminating focusing when equipments are suitably designed and accurately made. The head-lamp manufacturers have learned how to make and assemble reflectors and sockets accurately, and the filaments of incandescent lamps are practically all well within the 3/64-in. positioning tolerance of the S.A.E. Standard, with promise of further progress. The trend of the art with reference to the focusing matter is unmistakable.

Provision for the simple aiming of the head-lamps is, in any event, necessitated by the possibility of the displacement of the complete head-lamps through force. Aiming alone also compensates for variation of the light source above and below the focus. The results for equipments of both the older and newer types are shown in Table 2. Obviously, the beam pattern remains acceptable over the range of modern manufacturing variations. As indicated above, in a well-made equipment to contemplate total variations of 5/64 in. is no longer necessary. On the other hand, it is also apparent that, with suitably designed equipments, the total variation in the device and within the bulb may safely be somewhat greater than the 2/64 in. indicated by Mr. Porter.

THE WORK OF THE STEERING COMMITTEE

BY DR. C. H. SHARP[12]

ABSTRACT

IN the development of the automobile, engineers have devoted their attention mainly to improving acceleration, smoothness of action, quietness, speed, and economy; and other essential features have been overlooked. Until recently, brakes were neglected; now cars are sent out with good brakes, properly adjusted, that will work. Head-lamps have been used but their importance is just being realized. Lamps as defined by legislators have been adopted and undue glare has been reduced by the use of a lens. Now an effort is being made to determine the best driving-light that at the same time will produce the minimum obstruction to other drivers. The Illuminating Engineering Society endeavored to make the legislative specifications more definite by translating illumination into terms of candlepower and to reduce the glare by limiting the candlepower in certain regions. The present plan is to attempt better definitions, under the guidance of a Steering Committee, and to take advantage of the fact that an alternative beam is now allowable for use when passing other cars.

The chief problem is the limitation of glare; as this depends on the human factor, it can be arrived at only by consensus of opinion. When better knowledge of the limits of the illumination is secured, means will be developed for obtaining the desired result. The broad problem is to find out what is the most acceptable driving-light within the limitations of glare that it is possible to get at present.

THE idea that Commissioner Dill has suggested regarding the personnel of the Steering Committee, that is, that it should include representatives of the Hoover Conference, the Bureau of Stadards and the Eastern Conference of Motor-Vehicle Administrators, was considered in the formation of the Committee. E. C. Crittenden, of the Bureau of Standards, and A. W. Devine, of the Eastern Conference, are members, and Mr. Crane is chairman of the subcommittee of the Hoover Conference to do this work. Such cooperation as the Eastern Conference may be disposed to give to the Committee in the future will be most valuable. In

[10] See THE JOURNAL, February, 1926, p. 222.

[11] See THE JOURNAL, May, 1926, p. 470.

[12] M.S.A.E.—Technical director, Electrical Testing Laboratories, New York City.

the evolution of the automobile into a machine that runs with enormous acceleration, smoothness of action, quietness, speed and economy, certain features that are essential to a perfect automobile have been given secondary place.

For a while the brakes were neglected, but now brakes are put on that are adequate for the work they have to do. Cars are sent out from the factory with good brakes, properly adjusted and, I do not doubt, these greatly improved brakes are contributing largely at present to decreasing the number of traffic accidents.

Head-lamps are placed on the car, yes. But we are just waking up to the fact that this is not enough. Very much more is involved in proper and safe headlighting at all times, when it is possible under the existing conditions, than merely fixing a pair of projectors on the car.

Now what have we been doing? We have been going along for years with a definition of an adequate driving-light that was not made by engineers; it was made by legislators. They have said that an adequate light should illuminate the highway so that the driver can see a substantial object 200 ft. distant directly in front of the car. They have also said that it must not produce an undue or dangerous glare in the eyes of other users of the highway.

The Illuminating Engineering Society took the matter up when the situation was less acute than it has since become, based its specifications on the definition of a driving-light that the legislators gave but included a numerical definition of the minimum beam necessary to render an object visible 200 ft. in front of the car. It also endeavored to make the glare-specifications more definite through a maximum-candlepower figure in certain regions. Because the officers of the law had to administer it under some rational system, the specification so evolved at that time was adopted rather generally. The numerical values put into the specification were arrived at, not by guesswork, but as the result of painstaking, careful and extensive research, so far as the resources available at the time would allow.

Now the proposition is, to undertake with abundant resources and under the guidance of the Steering Committee, a scientific study of the problems of headlighting, with a view to determining what is the best practicable method of lighting the road ahead of cars, when all the limitations of the case are taken into consideration.

Practical considerations will be taken into account. For instance, the disposition on the part of the administrators appears to be to allow the use of a more effective driving beam, if an alternative beam is provided to be used when passing other cars.

In most States, dimming is contrary to the law, because the law says that the light must enable the driver to see a substantial object 200 ft. ahead; and that cannot be done with dimmers. The use of an alternative light, the depressed beam, will give the driver a light that will suit him better in passing another car and will also suit the other driver better. This is a system that ought to lead toward improvement all along the line and very quickly.

I think that the Steering Committee, which will have resources, money and brains at its disposal and, more than anything else, will have the backing of the automotive industry, will be able to reach a reasonably accurate answer to the question: What is the best in the way of a driving-light that we can get under the limitations of the problem? The chief difficulty is the limitation of glare, and this is a thing that it is impossible to figure out in a psychologist's or a physicist's laboratory or an engineer's office. That glare depends on the human factor has been made very clear by Mr. Crittenden; the best solution that can be arrived at is something in the nature of a consensus of opinion on the part of those familiar with the problem.

The specification is intended as a legal restriction; it does not point out the best driving-light. If Mr. Dill would not approve anything but the best light that can be produced, we should have to stop driving at night. Limitations should be imposed, and limitations exist beyond which we cannot go; that is to say, we must have more than the minimum driving-light in certain regions and less than the minimum glare. They do not say how much is allowable on the other side of those limits. They are not tolerances in the sense of plus and minus. They are one-way things and the whole field on one side or the other of those limits will be opened up when we get better knowledge of the situation.

When we get something better, to change the limits may possibly be necessary. I hardly think so, because they have been drawn very carefully in such a way that they are not restrictive of progress in the art. So, I think the Steering Committee has stated that it did not intend to look to the revision of the specification, but rather to the broad problem of finding out what is the most acceptable driving-light within the limitations of glare that it is possible to get at present. I am sure you all feel disposed to cooperate to the fullest degree in the solution of a problem that involves not only the comfort and safety of the automobilist on the road but, in view of the increasing traffic saturation on the road, is commercially very important. If the use of the automobile at night is to be restricted by bad headlighting, it will react on the sale of cars.

FACTORS IN HEADLIGHTING

BY J. H. HUNT[13]

ABSTRACT

AFTER emphasizing the importance of the sentiments expressed by Commissioner Dill, thanking Mr. Porter for the completeness of the data presented in his paper and agreeing with Mr. Falge with regard to making tests under all conditions, the author avers that enforcement officers and taxi-drivers are human and that it is also characteristic of human nature to believe that the particular solution of a problem that fits one's own needs is the answer desired. He supplements the remarks of Mr. Crittenden with the statement that, after all, headlighting problems are engineering problems and involve the use of science and horse sense and that sometimes data mean very little because all the factors have not been analyzed and the conditions properly controlled. Attention is called to the fact that many persons are permitted to drive cars who should not be allowed to do so because of mental and moral limitations.

I SHOULD like to see Commissioner Dill's remarks, complete, sent to every general manager in the industry. Sufficient copies should be supplied so that each general manager could pass them on to every individual in his organization who has anything to do with

[13] M.S.A.E.—Head of the electrical division, General Motors Corporation Research Laboratories, Detroit.

the headlighting problem. If Mr. Dill's speech were spread around in such a way, I think we would have a change of attitude on the part of some, and would have this problem pretty well under control. After they all have had a chance to go over Commissioner Dill's remarks, I believe we would no longer be troubled by the attitude that it is not necessary to stir up this headlighting problem. There has been some disposition to feel that we might let a sleeping dog lie. I think the dog is very much awake and that somebody will be bitten, if we do not "get busy."

As one engaged in research work and very much interested in this particular problem, I wish to take this opportunity to thank Mr. Porter for presenting the type of data that he has given us in such complete form[14]. I will say frankly that he has saved our own group considerable money in duplicating the test, and it is particularly generous on Mr. Porter's part to present the evidence he has because it supplies a certain amount of ammunition to the lampmaker, when he wants an alibi, and throws a certain amount of blame on the bulb manufacturer.

I wish to emphasize Mr. Falge's point with regard to testing under all conditions. I have gone far enough to know that the casual observation of any individual is of very little value in enabling him to arrive at a final solution.

Two points have been emphasized that are not news to us but are worth remembering. Commissioner Dill has assured us that he is very human even if he has the reputation of being hard-boiled. The data that Mr. Carlson has presented to us have assured us that the taxicab drivers in the City of Washington are also human and can see better when they have lights.

Characteristics of Human Nature

To believe that the particular solution of a problem which fits one's own particular needs is the answer is characteristic of human nature. In the headlighting problem that idea would cause considerable difficulty. As a representative of a manufacturing group, I am thoroughly convinced that anything entering into production must meet all the conditions fairly and satisfactorily. The information necessary to make that compromise cannot be secured unless we all work together. When the information gets around to the trade that the attitude of the representative of the public, and that is really the position that Commissioner Dill occupies, is such as he has expressed, it is pretty nearly time that we were doing something about it.

The remarks of Mr. Crittenden have, I think, convinced you of the difficulties of testing headlight illumination by pointing out the wide range of the factors involved. I would like to call the attention of the various representatives of the motor-car companies that are working on this problem to what he has said, and to add that, after all, our problems are engineering problems that involve the combined use of science and horse sense.

I have noticed among certain engineers with whom I have come into contact a disposition to feel that when they have used the methods of the scientist in some part of the problem, they have conducted a scientific test, whereas they may have failed to analyze all the factors and have obtained data that mean very little because the conditions were not properly controlled. A classic example of that attitude is the old story that we were told as freshmen about the young lieutenant who was a long distance from the base of supplies when he received instructions to report at once the exact distance across a river. He was able to obtain a transit, but he could find no accurate means of measuring the length of a line. He staked out his base-line, paced it off 100 times, computed the error by the method of least squares, and sent in a report that the distance was 934.593 ft.

Scientist's Point of View

On the part of the scientist who comes to an engineering problem I sometimes notice a disposition to say,

> There are all these factors to be considered—so many that we cannot separate their effects. A scientific guess is likely to give good enough results for commercial purposes.

To conduct a scientific test under road conditions will be impossible because the scientist likes to get about 30 ft. under ground in a thermostatically-controlled room and carry out his tests under the condition that he has only one variable which is accurately controlled.

The fact that we do not know all the factors, or cannot completely control them, does not justify taking data in a sloppy manner or saying that trying to use scientific methods is useless. We must do the best we can and then use horse sense, but we must use it at the proper time, when we are interpreting the results.

One more point that I wish to make does not apply directly to headlighting, but does apply to safety in night driving. We all realize that a large number of individuals should not be permitted to drive a car at all, because of certain mental and moral limitations. Many persons are driving cars at night under all sorts of conditions who should not be allowed to drive cars at night, or at least should not be allowed to drive cars except under carefully controlled conditions, on account of the limitations of those particular individuals in their ability to see under reduced illumination. As engineers, we cannot do anything about this. Such persons may ultimately become subject to legislation or regulation when we begin to control driving more carefully, but I am offering the idea as a suggestion that might, at some time or other, be worthy of more consideration.

[14] See The Journal, February, 1926, p. 222.

OUR FOREIGN TRADE

OUR expansion of foreign trade is a part of our domestic progress, both socially and economically. And in this progress I would first mention the accumulative value of the intensified education, both elementary and higher, that we have been dinning into the American youth over the last 35 years. In this time we have multiplied our students in institutions of higher learning by 400 per cent. Today we have more than all the rest of the world put together. We have trained technical personnel in every avenue of production and distribution upon a scale vastly larger than that possessed by any other nation. We have realized from this and many other causes a great advance in business organization and a great adaptability to new ideas and to shifting demand.

Our workpeople have increased in education and skill. We are reaping the benefits of some 600 industrial research laboratories, mostly established in the last 12 years. Under the pressure of high wages we have ruthlessly revised our industry with every new invention. We have had a great advantage in that by volume production, made possible through a great domestic market, we have been able by repetitive processes to apply or focus every advance into standard commodities of high quality and low cost of production.

National Efficiency Greatly Increased

By and large, while we have increased our population 16 or 17 per cent in a dozen years, we have swelled productivity of the Nation by something like 30 or 35 per cent. Our farms produce 13 per cent more with the same number of farmers as 12 years ago; our railways carry 22 per cent more traffic with about the same number of men. We now use some 68,000,000,000 kw-hr. annually, whereas we used 23,000,000,000 kw-hr. 12 years ago.

These are the reasons we are able to sell goods of high quality, produced under the highest real wages in the world, in competition with goods produced under lower standards of living. These methods are rooted not alone in technology. They are rooted in social conceptions that penetrate far deeper and not only promise greatly for the future in our standards of living at home, but provide the basic assurance of our continuing growth in foreign trade, both exports and imports. These are the fundamental forces that promise for us our share of the world's increasing demands even of competitive goods; if we keep them in motion.

It is not enough to produce high-quality goods at diminishing costs. Trade expansion calls for constantly better-organized and more-scientific selling. To create a sense of need abroad for our particular goods, to induce the purchase of them, is a science in itself. We need to concern ourselves with longer-view policies. Foreign markets are more difficult to establish than are domestic markets. They cannot be held by ruthlessly starving the foreign customer whenever the demand for goods at home increases, with the expectation that they can be expanded easily whenever we have a moment of depression. Foreign trade is a vital part of our whole system; it is not a spare part to be used in emergencies.

Goods sell upon service of the merchant as well as upon price and quality. We need more actual American wholesaling established in foreign markets. Too much of our export to neutral markets is a jobbing trade through the nationals of those countries with which we must compete. We are never secure from their natural preference for goods of their home country whenever it suits them.

Stabilization of Europe

The recovery of Europe will help our foreign trade. Trade grows on prosperity, not on poverty. I believe that in most trades it has been more difficult to compete with Europe in neutral markets in the last few years against the underpaid labor and lower overhead costs of depreciating currencies than it will be when Europe is more stable and they have recovered their pre-war standards of living.

In larger vision our export trade does not grow by supplanting of the other fellow but from the increased consuming power of the world. Our exports are not based on the destruction of our competitors but on insistence that we shall participate with them in the growth of world demand.

Fifty-two of the 70 nations of the world, including almost every important trading nation, increased their tariffs after the war. It might seem that these widespread protective policies would tend to localize industry and thus decrease the total volume of international trade. But it certainly appears that internal economic and social currents that make for prosperity or depression in a nation have a much larger effect upon the total volume of imports than the tariffs and thus more largely affect world trade as a whole. In our case, far from our present tariff diminishing our total imports, they have increased about 35 per cent since the higher tariff came into effect. This has also been the case with other nations that have progressed in internal economy. In any event our experience surely indicates that in considering the broad future of our trade we can dismiss the fear that our increased tariff would so diminish our total imports as to destroy the ability of other nations to buy from us.

Payment of War Debts

The war debt due us when settled upon our own views of the capacity to pay will yield about $300,000,000 per annum, although as yet the actual payments are much less than this. The private foreign loans and investments today require repayments in principal and interest of about $600,000,000 annually, or nearly twice the war debt. I have heard of no suggestion that interest and repayment of these private debts will bring the disaster attributed to the war debt. The question is of importance, however, as to how this $800,000,000 or $900,000,000 of annual payments may affect our merchandise movement. There is a compensating factor in American trade relations unique to our country which has a large bearing upon this question—that is, the vast dimension of our invisible exports in the form of tourist expenditure, emigrants' remittances and other forms of American expenditure abroad. These items in 1925 amounted to about $900,000,000, or about $100,000,000 more than our incoming payments on debts of all kinds. In other words, at this stage of calculation the balance of trade should be in our favor by about $100,000,000. But beyond this we are making, and shall long continue to make, loans abroad. For the last 4 years these loans have averaged nearly $700,000,000 a year, and in fact the merchandise balance in our favor has been running just about this amount.

There is no disastrous shift in our imports and exports of merchandise in prospect from debt causes. The economic advantage to foreign countries of our great financial strength in these times cannot be denied. Nor did we get this financial strength out of war profits. We lost enormously by the war. We created this reserve of capital, as any study of our economy will show, from our growth of efficiency, by hard work and savings since the war.

The Government is now deeply in the shipping business, and I believe must continue to operate upon routes where private operation cannot undertake it until the routes have been built-up to the point where private operation can undertake them. But we will never have a real or satisfactory merchant marine until it is owned and maintained by private enterprise. The Government cannot operate cheaply. It cannot secure revenue as large as private enterprise. It cannot avoid the interminable difficulties and wastes of bureaucracy and, above all, the direct and indirect political pressures. We must get out of Government operation as quickly as we can establish private operation.

By contributing to peace and economic stability, by the loan of our surplus savings abroad for productive purposes, by the spread of inventions over the world, we can contribute to the elevation of standards of living in foreign countries and the demand for all goods.

Ours is not a nation of factories, railroads, dynamos, warehouses, trade, or ships. It is a nation of men and women and children. When we consider the themes of production and trade, we need, indeed, to be guided in our conclusions by that course which will promote their welfare and comfort. If by our efforts and our discussions we enlarge their standards of living it is an economic thing, but it is a far greater thing than this, for security and living and comfort yield the opportunity for that greater fullness of life of the spirit, which is the true purpose of human service.—From an address by Secretary of Commerce Hoover before Export Managers Club of New York City.

IRON ORE PRODUCTION IN 1924

In 1924 the production and the shipments of iron ore decreased 22 and 25 per cent respectively as compared with 1923. The production ranked about with that of 1915 and was 99 per cent of the average for the preceding 5 years and 92 per cent of the average for the preceding 10 years. The output of pig iron decreased 22 per cent as compared with 1923 and was about 103 per cent of the average for the preceding 5 years and about 97 per cent of the average for the preceding 10 years. This output was about equal to that of 1919, which was the first year following the ending of the World War.

The average value per ton for iron ore at the mines decreased about 16 per cent and that of pig iron at the blast furnaces 13 per cent. The quoted prices of ferromanganese, spiegeleisen and steel showed considerable decreases. In operations, production and earnings the year 1924 was very disappointing to those connected with the iron and steel industry.

The steel industry had scarcely adjusted itself to the change from a 12 to an 8-hr. day that was brought about through Government influence in 1923, when in July, 1924, the Federal Trade Commission ordered the discontinuance of the system of basing steel prices on the price at the Pittsburgh mills plus the freight to destination. As this order did not become operative until September, its full effects had not become established at the close of the year. One immediate effect is said to have been the reduction of prices on several products to Western buyers, and some other effects were the establishment of several new basing points, the shifting of buying to more advantageous centers, plans for an increase of steel-making capacity in the Chicago district, and larger movement of steel products from the Pittsburgh district by barge to Memphis, New Orleans and other river points.

The railroads were the leading buyers of steel in 1924; they were followed by building and general construction; automobile, oil, gas, and mining industries; exports; agriculture; and machinery. All but the first two outlets for steel showed decreases.

The total domestic output of pig iron required probably about 59 per cent of the apparent maximum capacity of the Country, according to figures of the American Iron and Steel Institute; but this capacity was not utilized steadily, for at the beginning of 1924 only 239 furnaces were in blast; on June 30, 164; and at the end of the year, 235. The production of steel ingots is considered to have been about 63 per cent of capacity, the output having ranged from about 38 per cent of the capacity in July to 86 per cent in March. The output of pig iron in the United States represents about half of the world's production and is more than that of all the producing countries of Europe combined.

Iron ore mining in the Lake Superior district had a lean year in 1924 because of smaller demand and a cut of 80 cents per ton in ore prices. Eastern furnaces took virtually no Lake ore because they could obtain foreign ore more cheaply. Shipments did not reach consumption by about 2,000,000 tons. Both large producers who consume their own ore and independent producers undoubtedly sustained losses because in a year of small production overhead charges are larger in proportion, and in 1924 no reduction in such mining charges as labor, supplies and taxes were effected. Since the war the capacity of the mines has considerably exceeded the normal consumption of ore, and this tends to maintain high charges of overhead and interest. Immense sums are being paid in taxes by the iron-mining companies in Minnesota, the total for 1924 being considered approximately $28,000,000; this sum, if borne by 31,076,000 tons of ore valued at $93,311,000, indicates nearly 30 per cent of the value of the ore at the mine. The season of 1924 ended with stock piles larger than at the close of 1923, especially on the Marquette and other Michigan ranges. The total increase in stocks in the Lake Superior district amounted to 21 per cent. —From Bureau of Mines Report by E. F. Burchard and H. W. Davis.

SIMPLIFIED PRACTICE RECOMMENDATIONS

In the 55 simplifications completed by the Division of Simplified Practice of the Department of Commerce, the grand-average elimination runs so close to 80 per cent that the Division feels that 80 per cent of the business is done in 20 per cent of the varieties offered to the public by the manufacturers.

A recent audit of 11 recommendations shows the average percentage of adherence or degree of observance is 82 per cent. In these lines, from 64 to 99 per cent of last year's output was in accord with the simplified lines. R. M. Hudson, chief of the Division of Simplified Practice, states that savings estimated by leaders in different fields range from $1,000,000 per year in paving bricks to $200,000,000 per year in lumber.

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Coordinating Gear Design and Production Methods

By Perry L. Tenney[1]

Production Meeting Paper

THE discussion following the presentation of this paper at the Production Meeting held on Sept. 15, 1925, in Cleveland, was constituted of remarks made from the floor. In accordance with the usual practice, the stenographic report of these remarks has been submitted to the various speakers for their approval and to the author for any additional comment that he cared to make. The corrected discussion, as received, is printed below. An abstract of the paper precedes the discussion so that those of the members who did not read the paper when it was printed in the October, 1925, issue of The Journal can use it for reference.

ABSTRACT

PERIODICALLY recurring problems of gear noise and wear which seem to arise from no specific cause frequently affect the manufacturing side of the automotive industry and especially the gear-manufacturers. While much has been written and discussed about the mathematics and geometry of gears, which should overcome all of these problems, the trouble unfortunately still persists. The paper outlines the experience of the organization with which the author is connected in solving a rather difficult problem that offered an opportunity for a more thorough analysis than did its predecessors. Laboratory and dynamometer analyses of the product showed that it compared favorably with the output of other factories. Throughout the entire preliminary investigation evidence was found that the coordination of the high points found in each steel as furnished by the mill, its heat-treatment, the details of the tooth form, the mathematics of gear action and the manufacturing processes would enable great strides to be made in both increasing the performance and reducing the cost of the product.

The first point attacked was the steel, which was a No. 5150 S.A.E. Steel that had been substituted some years before for the chrome-vanadium No. 6145 steel originally used. A series of tests was made on practically the entire group of chrome-carbon, chrome-vanadium, chrome-manganese, manganese-molybdenum and chrome-nickel steels, using the lead-pot, salt-bath, cyanide and electric-furnace methods of heat-treatment. While the conclusion reached was that very little difference in the performance of any of these steels with normal treatment could be detected, the high wear-value of cyanide-treated chrome-steel and the even better value of chrome-vanadium steel when cyanide treated were the two outstanding features. In every case a metallurgical representative from the steel mill worked with the organization's metallurgist so as to take advantage of all the knowledge available for getting the best results from each type of steel. These tests furnished the basis for probably the most vital information required for motor-car-transmission design, the ratio of dynamometer hours to miles of field operation of the car in intermediate gear. This figure varied from 1:1000 to 1:8000, a safe average being 1:3000.

A study of the characteristics of the wear of the first series of dynamometer tests revived interest in some calculations and tests that had previously been made on modified-addenda gears, it being apparent that the wear on the gear tooth bore a definite relation to the square inches of active tooth surface rather than to merely the pressure per lineal inch on the tooth. This resulted in an effort to make the number of square inches of active tooth surface on each pair of gears as nearly equal as possible, with the result that a reduction of 20 per cent in the weight of a transmission of a given capacity was effected.

Another example of coordinated activity was the grinding of gear teeth. About 3 years ago the decision was made that the gear teeth should be ground. After installing a battery of gear-tooth grinding-machines operating on the generating principle, it was found that a consistently good production could not be obtained and the form-wheel type of machine was substituted, the reason for the change being that the principles of approved grinding-machine construction and grinding-wheel practice were not violated and that the degree of accuracy required is merely a matter of machine maintenance and proper attention to the forming device.

As the result of the fullest cooperation from the steel mill, the forge shop, the heat-treating and metallurgical departments, the machine-tool builder, the grinding-wheel manufacturer and the engineer, the immediate problems of the factory and its customer have been solved, the gear-noise problem has not recurred to any great extent and the likelihood of its recurring in the future has been reduced. A greatly improved product, with in most instances a lowered cost has followed, but the most valuable accomplishment in the author's opinion is the bringing about of a spirit of cooperation in the shop and with the customer.

THE DISCUSSION

Chairman H. W. Alden[2]:—Periodic gear-trouble is interesting, because it seems to be chronic; it would be fine if some one would cure it, but solving gear troubles wholly on a mathematical basis is wrong. This is a very radical statement. I do not know now whether we are on the track of the proper remedy, but we will have some information to present soon. Evidently, the General Motors Corporation's experience is the same as ours; that is, every step of gear making must be watched. When that is done, what kind of steel you use makes little difference. When you become accustomed to the use of a certain steel, stick to it; that has been our slogan. Occasionally we have experimented to find more suitable steel but, after we try it out, we always come back to the No. 6115 S.A.E. steel.

Arthur L. Stewart[3]:—Bevel-gears demand constant attention during manufacture. Grinding interests us and we have done some experimental grinding of gears, but we have not progressed far enough to announce definite facts regarding the grinding of spur-gears, although we are working along that line.

Question:—How are the addenda of gears modified?

P. L. Tenney:—The basis of gear-addenda modifica-

[1] M.S.A.E.—Chief engineer, Muncie Products division of the General Motors Corporation, Muncie, Ind.

[2] M.S.A.E.—Chairman of the board of directors, Timken-Detroit Axle Co., Detroit.

[3] M.S.A.E.—Chief engineer, Gleason Works, Rochester, N. Y.

tion is to provide the maximum surface on each pair of gears. The results stated were not obtained with reference to strength, as several calculations have been in the past. The strength factors on any transmission we have seen are thus far greater than our wear factors and, with any reasonable design, the strength calculation practically can be neglected. Our company has been trying to get the best wearing value and to equalize the life of each gear.

R. H. SHERRY[4]:—The subject of steel and its treatment has a great interest for those using carburized gears who would like to change to the more easily treated oil-tempered gear. Practically all automobile gears were carburized in the early period of manufacture until the oil-tempered gear was introduced. Many makers had considerable difficulty with pitting of oil-hardened gears, sometimes because the carbon was too low but more frequently because the tooth face was too small for the load and required an increase in the tooth face. It would be of interest to many who are considering a change from carburized to tempered steel if in your investigations you found any particular steel that stood-up better than the others, or if you had worked out some special treatment that might make such a change possible without changing the size of the gears.

MR. TENNEY:—Formerly, we made carburized gears, but the difference in having several days of work between the gear-cutting machine and the test-stand made us favor the high-carbon gear. We had spalling and pitting at first, but it was of an entirely different nature in the case of the high-carbon gear. We have not experienced the so-called spalling or pitting on the pack-hardened test-gears that have been run through the dynamometer test recently or in trucks on the proving grounds.

MR. SHERRY:—About 1914, when the change in the type of steel was made by a number of manufacturers, pitting of the tooth surface was often a serious problem to those who had adopted oil-tempered steel. One manufacturer recently ran into the same trouble, although a high-carbon steel was used and the teeth were ground. Treatment, including the electric-furnace treatment was of no help. Another manufacturer overcame the trouble by hardening the gears with cyanide to obtain a greater hardness on the tooth face. Have you found any other treatment or any special steel that, with perhaps special treatment, will make a change from carburized to tempered steel possible without change in the size of the gears?

MR. TENNEY:—The high-carbon straight-chrome steel having electric-furnace treatment was used, but we soon exhausted its apparent possibilities. The remedy, on the 20 and 25 combination, 45 teeth in the test train, which has increased from 2 hr. at the start of pitting to an average of 10 hr. before pitting and from 26 to 30-hr. length of life was by using the cyanide treatment on chrome steel of 50-point carbon-content.

QUESTION:—What has been done toward using plain bearings and large shafts in transmissions to obtain a more rigid mounting?

MR. TENNEY:—Our experience in using the plain bearings is not satisfactory. Many good reasons exist for using plain bearings, but we have tried all the fancy metals and have abandoned them on account of the difficulty of lubricating them. If a bearing can be lubricated when the load is first thrown-on, enough to keep it from seizing, progress will be made. We have changed and now use the lighter series bearing and a larger shaft, thus eliminating deflection. Then we use a No. 1200-series bearing instead of a No. 1300 series. We have had no success with plain bearings under high pressure; in fact, all our development in reducing the size and cost of the transmission has been to reduce the size of the gears and so get rid of an excess of cast iron to surround them. We have been willing to spend more money on a gearset to make it smaller and thus use less material to surround it and hold it onto the engine. It appears that the trend in that direction is away from the plain bearings. Our plain bearings, for countershafts on transmissions of conventional design, will stand-up as long as the gears. We had trouble on the pilot bearing, for this limitation does not allow sufficient area or pressure to obtain proper length of life.

QUESTION:—You overcame pitting in treated gears by hardening them in cyanide; what do you do when you grind the teeth, what hardness did you get in the treated gears and what hardness did you get in the cyanide-hardened gears?

MR. TENNEY:—On No. 5150 steel, we found that the grinding lengthened the life of an electric-furnace or lead-pot gear, but that it would shorten the life of a cyanided gear. The general idea of cyanide treatment seems to come from the toolroom. We cyanided a small piece of low-carbon steel, the penetration being 0.002 to 0.003 in., and obtained surprisingly good results; but that is in no way related to the treatment of high-carbon gears in a cyanide bath. I do not know how much the 0.003 or the 0.005-in. penetration has to do with the life of the gear, but the evidence points to benefit from the cyanide method. It prevents surface decarbonization during the heat-treatment. We also give steel what is called a "stringent quench." Instead of allowing an oxide face, which becomes a heat insulator for the gear, the stringent quench provides an absolute bond or contact with the quenching medium, giving a high martensitic structure of about 0.017 to 0.020 in. thickness similar to a case. Under the microscope, this portion shows a higher-grade structure than the body of the gear. Compared with the electric-furnace gear quenched at the same temperature, a blanket of oxide plus whatever decarbonization there may be produces a lower hardness value on the surface of the gear than there is in the actual core or body of the steel. Where we cyanide, we get about 0.017 in. of higher value. If you grind off a portion of the lead-pot gear, you will improve the gear. What we are all seeking is to put dollars of transmission value into a piece of steel and our attitude is that, with the present chrome-nickel or the chrome-vanadium gears, we do not get the best results when grinding them.

QUESTION:—Do the clash ends of cyanided gear-teeth wear well in service, or do they show flattening due to impact as the gears are shifted?

MR. TENNEY:—We find no difference in this respect, comparing the cyanided gear with any of the other treatments, except that the cyanide treatment produces a good surface. Our chrome-vanadium-gear tests have proved that not so much trouble from surface breaking is experienced, whereas, in the case of pack-hardened gears, a surface abrasion will show; but we have not found that the cyanide has any effect on these gears. The subject of chamfering, to see that we get the points of clash far enough back toward the pitch-circles to prevent surface abrasions is important and should be studied.

QUESTION:—What are the proportions of the cyanide bath?

MR. TENNEY:—The cyanide content can run down to 3 per cent, but this endangers decarbonizing. We tried

[4] M.S.A.E.—Consulting metallurgical and industrial engineer, Evanston, Ill.

to run at 10 per cent but found that the treatment got away from us very frequently, especially on a gear forging that did not have the recesses clear of scale. We found that with the presence of scale the affinity for the cyanide would quickly rob the bath, so we went back to the 45-per cent bath and stayed with it for safety's sake.

QUESTION:—Did you try the gear-tooth grinding-machine now being built by the Walcott Lathe Co., formerly known as the American or Ott gear-grinding machine?

MR. TENNEY:—No. We have seen it and it is very much like some others; we did not care to try several of the same type at the same time.

QUESTION:—Was a true-involute or a modified-involute form of tooth used in connection with form-wheel grinding, and what was the lowest number of teeth so ground?

MR. TENNEY:—We have found it advisible to hold as closely as possible to the true-involute tooth. The only modification is a slight entry-allowance. We consider tooth deflection and the striking of the sharp edges, but we feel safe in getting say 0.002-in. entry-allowance, although we have not proved yet just how much is best. The more accurate the gears are, the closer we can conform to the true-involute form.

QUESTION:—What steel gives the best results?

MR. TENNEY:—As a result of these tests, we are now using No. 5150 and No. 6150 steels on a selected carbon range of 5 points. I do not know what the rest of our tests will indicate, for they may indicate something else later; but these steels have been the most satisfactory so far.

QUESTION:—At what engine-speed were the dynamometer tests made?

MR. TENNEY:—Our dynamometer tests were based on 90 lb-ft. and 1700 r.p.m. We have several motor cars that run all the way up to 120 lb-ft. but, considering any one of the engines as it goes to work on the transmission, we find it will average close to 90 lb-ft. and up to 100 lb-ft.; so, we used the one size of gear and one reasonable dynamometer-ratio and tried to duplicate what the engine would give, rather than trying to raise the pressure and cut the time down. We put three shifts on it and ran the test night and day. One can seldom draw safe conclusions from reconstructed tests. Then we compared this test with one behind the engine and found that our 90 lb-ft. estimate was not far wrong. The performance was nearly the same as that of the gas-engine test. We merely selected 90 lb-ft. because it happened to be the right loading for the size of engines on which we desired to base all our comparative tests.

QUESTION:—Was any nitrogen-iron combination formed in the successful cyanide-treatment? This is asked because of Krupp's experiments with the nitrogen treatment of steel.

MR. TENNEY:—We have heard metallurgists argue about the effects of cyanide, regarding the needle formations and the nitrogen penetration, and we receive statements that there is some, and then we receive statements that it cannot be found. So far as we have gone, we have found no apparent effects of nitrogen. In fact we do not know that anything is there, from tests that have been made in the laboratory. We have had several arguments, but none of them seem to have been able to substantiate the definite statement.

QUESTION:—Did you try the Maag grinding machine having the automatic-disc truing-device?

MR. TENNEY:—We did not try it, but we looked at what the Pratt & Whitney Co. is doing. We were working on another machine of a much greater speed and it seems promising, but we have limited our tests to just what we could do, for we did not intend to run universal tests of what all machines would do.

QUESTION:—What effect did the cyaniding of gears have on gear noise?

MR. TENNEY:—We had gear noise in the shop for 3 days, in one instance, and cyanided the gears to make them quiet. That was the actual shop result but, due to the fact that the cyanided gears had a harder surface, the noise from the cyanided gears was of higher pitch than that from the lead-pot gears. However, when we cut the gears properly, have the shape just right and have a job with which we feel satisfied, the cyanide gears are just as quiet as the others. The oil-hardened gears did not have the high-pitched sound and so we used the oil-hardened steel but, regarding the cyanide treatment itself, aside from getting a high-pitched sound from the new gear after the fuzz wears off, they are all alike.

QUESTION:—What type of tooth do you consider the best for grinding the stub, 20-deg. or the standard 14½-deg.?

MR. TENNEY:—Our experience is that the type of tooth does not enter into it; in other words, the type of tooth that is best for transmitting the power should be used, but the type does not enter into the grinding situation.

R. S. DRUMMOND[5]:—The tendency in the design of gear teeth during the last 3 years has been toward longer teeth of a given pitch. We have used teeth of unusual length in a number of jobs with great success where quietness of operation was important. In the past, the ordinary stub-tooth design has been used in a number of jobs in which it was improper to use such design because quietness was very important. Some engineers have carried the stub design even below the specified dimensions.

The usual specifications of the stub tooth such as 7-9 indicates a 7-pitch tooth with the height of a 9-pitch tooth. We have made many designs of "anti-stub" which have a length greater than the normal length for the indicated pitch. Thus, we have made designs of ground gears of 6-pitch with 4-pitch length. This, in a normal design, would be 6-pitch with 6-length and, in the stub design, it would be 6-pitch with 8-length. We have also designed gears of 7-pitch with 5-length, 8-pitch with 6-length and even as fine as 16-pitch with 12-length. This change in tooth design represents a new practice in the industry and introduces new results in the final product.

As an indication of the unusual results obtained from this type of gear, we cite the use of 16-pitch teeth with 12-pitch length in use in a standard motor-car as an over-speed drive, the remainder of the gearset being standard 7-pitch. The 7-pitch teeth showed considerable wear after 10,000 miles use, whereas, the 16-pitch teeth did not show wear. This development has given its maximum benefit to the industry in timing-gears and over-speed transmission-drives where the noise factor and length of life are the important features.

No difficulty is experienced in grinding these teeth of unusual length by the formed-wheel process, but it is difficult to get a generating wheel against this deep surface and to maintain rigidity of the grinding medium. Tooth gears have been form-ground as large as 0.75 pitch and as large as 1 ton in weight; and as small as 22-pitch gears weighing less than ½ oz. I have as a pocket piece a 22-pitch gear that is accurately ground. The machine that ground this piece, or a similar design, will grind a gear of 0.75 pitch weighing 1 ton.

[5] M.S.A.E.—Vice-president, Gear Grinding Machine Co., Detroit.

The tendency today is away from the stub-tooth design, and we commend the use of the so-called "anti-stub" tooth.

My experience concerning distortion of gears has been that the greatest change in heat-treatment occurs in mis-forming the shape of the tooth as to tooth form, the indexing and runout changes being secondary evils with relation to heat-treatment.

We frequently have panaceas offered for gear troubles, and one of the recent ones is the use of cyanide surface-treatment instead of case-hardening. It is well to bear in mind that any heating of the steel will cause distortion in the tooth due to the relief of the internal strain, and that any hardening result will give additional distortion of an unequal character in the different parts of the gear.

We do not believe that the use of a cyanide surface-treatment will, in itself, solve the gear trouble due to ordinary heat-treatment; it will not correct, but will aggravate distortion.

MR. TENNEY:—I cannot say that the cyanide is good for correcting, but we found that one characteristic is the constant growth. So far as distortion itself is concerned, due to the better heating, we had less distortion troubles; but, aside from that, the higher constant-growth was the only general characteristic.

CHARLES G. YOUNG

AN Associated Press dispatch from San Juan, P. R., dated June 17, announced the sudden death there of Charles G. Young, at the home of Adjutant-General John A. Wilson, apparently of heart failure. At the time of his death Mr. Young was consulting engineer of the C. G. Young Co., of New York City, and had been in Santo Domingo recently in connection with an engineering project. About 2 months previously he had returned to New York City from Porto Rico and visited the Research Department of the Society in quest of cost figures on automotive transportation. He was elected to membership in the Society with the grade of Member on Dec. 10, 1919, at which time he was connected with the John N. Willys Export Corporation, in New York City, for which he was engaged in making investigations of foreign markets.

Mr. Young was born at Bath, N. Y., on Nov. 1, 1866, and received his technical education at Haverling Academy, supplemented by tutoring in physics and electrical and chemical engineering. Prior to his connection with the John N. Willys Export Corporation mentioned above he was successively mechanical student with the Schuyler Electrical Mfg. Co., Hartford, Conn.; general superintendent of the Mount Morris Electric Light Co., New York City; construction manager of the J. G. White Co., of New York City and London; consulting engineer in New York City; and in charge of engineering and valuations for Ford, Bacon & Davis, New York City.

Mr. Young was a fellow of the American Institute of Electrical Engineers and a member of the New York Electrical Society, American Society of Civil Engineers, Pan-American Society, Pan-American Chamber of Commerce, Engineers Club, Railroad Club, Circumnavigators Club, and the Adirondack League. He was connected with the New York Police Department for 3 years and resigned the position of secretary to Commissioner Richard E. Enright last December to undertake the reorganization of traffic control in two of the larger and more progressive cities in the West Indies.

GEORGE H. KLEINERT

THE death of George H. Kleinert, of Detroit, at Mount Clemens, Mich., on June 12, is reported. Funeral services were held on June 16 at his residence in Detroit, and interment was made in Woodmere Cemetery. At the time of his death Mr. Kleinert was factory manager of the McGraw plant of the Kelsey Wheel Co. He is survived by his wife, two daughters and two sons.

Mr. Kleinert was born in Germany in 1866 but was brought to this Country at the age of 2½ years and took out citizenship papers after becoming of age. For the last 28 years he had been connected principally with automotive engine and parts companies in Cleveland and Detroit, in executive capacities, such as factory manager, production manager, mechanical supervisor, and plant manager. His successive connections were with the Foos Gas Engine Co., Springfield, Ohio; American Multigraph Co., Cleveland; E-M-F Automobile Co., Detroit; Northway Motor & Mfg. Co., Detroit; Murphy Potter Co., Flint, Mich.; Wilson Fastener Co., Cleveland; Standard Parts Co., Cleveland; and last, Kelsey Wheel Co., Detroit.

Mr. Kleinert was elected to Member grade in the Society on Nov. 20, 1918.

Applicants *for* Membership

The applications for membership received between May 15 and June 15, 1926, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALLEN, FRED E., superintendent, Auburn Button Works, Inc., *Auburn, N. Y.*

ARMITAGE, A. D., vice-president, general manager and chairman of the board, J. H. Williams & Co., *Buffalo.*

BECKER, WALTER C., assistant superintendent of utility department, Chicago Surface Lines, *Chicago.*

BEHRENS, WILLIAM, draftsman, Buda Co., *Harvey, Ill.*

BLEECKER, JOHN S., transportation engineer, Day & Zimmermann, Inc., *Philadelphia.*

BRANDT, A. J., vice-president, Oakland Motor Car Co., *Pontiac, Mich.*

BROWN, E. A., service and sales department, Brown-Lipe Gear Co., *Syracuse, N. Y.*

CHALMERS, J. D., in charge of automotive costs and statistics, Shell Co. of California, *Seattle, Wash.*

CHATTERTON, W., JR., clerk, General Motors Export Co., *New York City.*

COFFINGER, A. W., designer and layout work, General Motors Truck Co., *Pontiac, Mich.*

COLE, D. S., research engineer, Leece-Neville Co., *Cleveland.*

COOLEY, JAMES H., superintendent of branch house motor equipment, Armour & Co., *Chicago.*

DAVIDSON, WILLIAM JOSEPH, engineering executive, General Motors Corporation, *Detroit.*

DEAVER, L. A., manager of technical and tire divisions, B. F. Goodrich Co., *Akron, Ohio.*

DENTON, CLAYTON E., assistant service manager, Reo Motor Car Co., *Los Angeles.*

DEUBLE, N. L., metallurgist, United Alloy Steel Corporation, *Canton, Ohio.*

DIBBLE, GEORGE C., Boyer Fire Apparatus Co., *Logansport, Ind.*

DOLE, JOHN L., secretary, Dole Valve Co., *Chicago.*

FOX, FREDERICK STRACHAN, consulting engineer, *Coventry, Warwickshire, England.*

GEBHARDT, EDWARD H., draftsman, Hall-Scott Motor Car Co., *Berkeley, Cal.*

GIBSON, ARCHIE R. M., service manager, Greer College of Automotive Engineering, *Chicago.*

HANNI, HERMAN, general manager, Scintilla Magneto Co., Inc., *Sidney, N. Y.*

HANSA, CHARLES, service manager, Bonwit Teller & Co., *New York City.*

HERBERT, HOWARD D., assistant general manager, Lambert Tire & Rubber Co., *Barberton, Ohio.*

HERRICK, K. F., service manager, Brown-Lipe Gear Co., *Syracuse, N. Y.*

HESSLER, ROBERT V., eastern sales representative, Brown-Lipe Gear Co., *Syracuse, N. Y.*

HORN, G. B., chief engineer, Dudlo Mfg. Corporation, *Fort Wayne, Ind.*

HORST, A., foreman, Troy Motor Sales Co., *Los Angeles.*

HOSAC, WIRT E., vice-president, Rolls-Royce of America, Inc., *Springfield, Mass.*

HUTCHISON, ARTHUR E., service engineer, Simplex Piston Ring Co., *Cleveland.*

JACOBS, G. A., general manager, Dudlo Mfg. Corporation, *Fort Wayne, Ind.*

JOHNSTON, JOHN OGLE, assistant works manager, Thornycroft of Australia, Ltd., *Sydney, New South Wales.*

JOYCE, TEMPLE N., special representative, Curtis Aeroplane & Motor Corporation, *Garden City, N. Y.*

LANDRY, PAUL, draftsman, Ford Motor Co., *Dearborn, Mich.*

LANSING, FRANK E., lubrication engineer and special representative, Sinclair Refining Co., *Philadelphia.*

LARSON, HAROLD E., master mechanic, Northland Transportation Co., *Minneapolis.*

LEFLER, MELVIN N., engineer, Lundelius & Eccleston, *Los Angeles.*

LEWIS, HOWARD B., experimental engineer, Hughes Tool Co., *Houston, Tex.*

LINKE, FRANCIS J., service manager, American La France Fire Engine Co., *Elmira, N. Y.*

LOTT, EGBERT P., manager of operations, National Air Transport Inc., *Chicago.*

McINTYRE, S. S., vice-president, Skagit Steel & Iron Works, *Sedro-Woolley, Wash.*

MACNEIL, CHARLES I., graduate student in mechanical engineering, Drexel Institute, *Philadelphia.*

MANNING, WILLIAM HEWSON, research engineer, General Motors Corporation Research Laboratories, *Detroit.*

MARCUS, WALTER, manager and engineer of production machine-shops, Horchwerke, Aktiengesellschaft, *Zwickau, Saxony, Germany.*

MINER, HARRY G., research engineer, Studebaker Corporation of America, *Detroit.*

MOORE, R. ALFRED, lubricating engineer, Skelly Oil Co., *Eldorado, Kan.*

NOTTINGHAM, EDWIN S., assistant sales manager, Brown-Lipe Gear Co., *Syracuse, N. Y.*

PIERCE, HENRY A., manager of Chicago Office, Brown-Lipe Gear Co., *Syracuse, N. Y.*

RAMSEY, PAUL, draftsman, Olds Motor Works, *Lansing, Mich.*

REINHARD, ROBERT N., manager of transportation, Burr Creamery Corporation, *Los Angeles.*

REMIG, PHILIP W., JR., engineer, Vacuum Oil Co., *New York City.*

ROBERTS, HARRY FRANK, production clerk, Ford Motor Co., *Highland Park, Mich.*

ROBERTS, WILLIAM HULL, assistant service manager, Nash Buffalo Corporation, *Buffalo.*

ROHM, HAROLD V., sales representative, Briggs & Stratton Corporation, *Milwaukee.*

ROWELL, B. A., manager of refined oil sales, Gilmore Oil Co., *Los Angeles.*

RUFF, ALBERT E., draftsman, International Motor Co., *Long Island City, N. Y.*

SHAY, BENJAMIN M., branch manager, G. A. Schacht Motor Truck Co., *Newark, N. J.*

SMITH, HARRY G., superintendent of Air Mail Service repair depot, *Maywood, Ill.*

SOUNITZA, W., mechanical engineer, Azneft Government Oil Fields, *Bakou, U. S. S. R.*

SPASE, CHARLES B., assistant engineer, Brown-Lipe Gear Co., *Syracuse, N. Y.*

STICH, GEORGE I., president, Aero Supply Mfg. Co., *College Point, N. Y.*

SZILASI, BELA, manager, Deutsche Erdol-Aktiengesellschaft, *Berlin-Schoneberg, Germany.*

TALLMAN, A. H., president, Tallman Brass & Metal Ltd., *Hamilton, Ont., Canada.*

TROLL, HERMAN, automotive engineer, L. Markle & Co., *Chicago.*

TUCKWELL, ARTHUR JOHN, superintendent of storage-battery division, Prest-O-Lite Co., *Toronto, Ont., Canada.*

WARREN, KENNETH W., design engineer, Continental Motors Corporation, *Detroit.*

WESTPHAL, WALTER R., student, Case School of Applied Science, *Cleveland.*

WHITTELSEY, CHARLES BARNEY, JR., assistant to general manager, Society of Automotive Engineers, Inc., *New York City.*

WILKIN, ROBERT E., chemical engineer, Standard Oil Co. of Indiana, *Whiting, Ind.*

WOODRUFF, DOUGLAS, treasurer and general manager, Auburn Button Works, Inc., *Auburn, N. Y.*

WYMAN, O. C., general manager, Central Casting Corporation, *Los Angeles.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between May 10, and June 10, 1926. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

AFF, LOUIS WILLIAM (A) owner, L. W. Aff Cylinder & Machine Works, 231 Ninth Street, *San Francisco*.

AMBROSE, ROY B. (M) manager of buildings, Carnegie Institute of Technology, Schenley Park, *Pittsburgh*.

BANKS, S. J. E. (F M) general manager, Automobiles M. Berliet, Richmond Bridge Works, Cambridge Road, *Twickenham near London*.

BARRETT, CHARLES G. (M) sales engineer, Nordberg Mfg. Co., *Milwaukee;* (mail) 1544 Maryland Avenue.

BINDER, JOHN A. (A) engineer, Dodge Bros., Inc., *Detroit;* (mail) 1895 Grand Boulevard, East.

BITNER, EDWARD H. (A) supervisor of motor vehicles, Bell Telephone Co. of Pennsylvania, *Harrisburg, Pa.;* (mail) 1949 Mulberry Street.

BLUME WILLIAM A. (M) engineer, American Brake Shoe & Foundry Co., New York City; (mail) 54 Park Avenue, *Suffern, N. Y.*

BUETHE, AUGUST, JR. (A) superintendent, Lexington Machine Co., *Rochester, N. Y.;* (mail) 477 Flower City Park.

CHOATE, CHARLES ALLEN (A) supervisor of motor engineering department, Provincial Institute of Technology & Art, *Calgary, Alta., Canada*.

CLO, J. HARRY (M) research engineer, A. Schrader's Son, Inc., 470 Vanderbilt Avenue, *Brooklyn, N. Y.*

DE ROZA, ROBERT J. (A) assistant manager, Federal Motor Co. of California, 1350 Howard Street, *San Francisco*.

DICKEY, RICHARD J. (A) chief engineer, Gabriel Mfg. Co., 1407 East 40th Street, *Cleveland*.

DUGGAN, JOHN ROSS (A) export manager, Westinghouse Union Battery Co., Swissvale, Pa.; (mail) 115 West 16th Street, *New York City*.

FISHER, LAWRENCE P. (M) president, Cadillac Motor Car Co., 2860 Clark Avenue, *Detroit*.

FITZGERALD, EDWARD (J) draftsman, Cruban Machine & Steel Corporation, New York City; (mail) 94 Lexington Avenue, *Jersey City, N. J.*

FUNNELL, HARRY M. (A) layout engineer, Spicer Mfg. Corporation, South Plainfield, N. J.; (mail) 597 Prospect Avenue, *New Market, N. J.*

GALBRAITH, L. E. (A) engineer, Toledo Steel Products Co., *Toledo;* (mail) 1541 Milburn Avenue.

HANDS, RONALD C. (A) assistant superintendent of yard department, Eastman Kodak Co., Kodak Park, *Rochester, N. Y.*

HASELTINE, C. W. (A) secretary and treasurer, International Motor Co., 25 Broadway, *New York City*.

HERLIHY, FRED W. (A) engineer, commercial-car department, Vacuum Oil Co., 49 Federal Street, *Boston*.

HIRSCH, ROBERT R. (A) district sales manager, S K F Industries, Inc., 317 Fidelity Building, *Buffalo*.

HOLLANDSWORTH, G. C. (M) chief engineer, Reliable Trucks, Inc., 3927 South Michigan Avenue, *Chicago*.

HOYT, ALFRED O. (A) general manager, Reliable Trucks, Inc., 3927 South Michigan Avenue, *Chicago*.

JOHANSEN, HARRY V. (A) sales engineer, Brandenburg Bros. & Eccleston, 704 Kresge Building, *Detroit*.

JONES, CLYDE RANDOLPH (A) owner, Service Garage, *Pasadena, Cal.;* (mail) 334 North Madison Avenue.

KING, VERNON BICKLE (J) technical apprentice, White Motor Co., *Cleveland;* (mail) 7801 Euclid Avenue.

LIDDELL, ROBERT P. F. (M) chief engineer, Motor Improvements, Inc., 365 Frelinghuysen Avenue, *Newark, N. J.*

MACCRACKEN, WILLIAM P., JR. (A) member of firm, Montgomery, Hart & Smith, 959 The Rookery, 209 South LaSalle Street, *Chicago*.

MOORMAN, A. H. (A) vice-president and treasurer, Wills Sainte Claire, Inc., *Marysville, Mich.*

MOULDING, THOMAS G. (M) chief engineer, Ramspring Bumper Co., *Chicago;* (mail) 1600 Albion Avenue.

PACKARD, JOSEPH A. (J) engineering secretary, White Motor Co., *Cleveland;* (mail) 14014 Woodworth Road, *East Cleveland, Ohio*.

PATRICK, ROBERT A. (A) plant manager, Columbian Bronze Corporation, *Freeport, N. Y.;* (mail) 15 Whaley Street.

PHILLIPS, HAROLD IRVING (M) sales engineer, Flintlock Corporation, *Detroit;* (mail) 318 Philip Avenue, North.

PITCAIRN, HAROLD F. (A) owner, Pitcairn Aviation, 1830 Land Title Building, *Philadelphia*.

SCHENCK, PAUL F. (J) chief instructor in automotive training, Board of Education, *Dayton, Ohio;* (mail) 707 North Broadway.

SCHINDEWOLF, A. K. (J) draftsman, Huff-Daland Airplanes, Inc., Bristol, Pa.; (mail) 42 Ellsworth Avenue, *Trenton, N. J.*

SCOTT, EVERET CHAPIN (A) first vice-president in charge of sales, Sterrett & Co., *City of Washington;* (mail) 3601 Porter Street, Northwest.

SOCIETA ANONIMA AUTOMOBILI ANSALDO (Aff.) Casella Postale No. 452, *Turin, Italy;*
Representatives: Borsieri, Isaac, works superintendent.
Soria, Guido, engineer and managing director.

STARLING, F. M. (A) lubricating, fuel salesman, Standard Oil Co. of New York, New York City; (mail) c/o Standard Oil Co. of New York, *Singapore, Straits Settlements*.

STAY, T. D. (M) manager and technical supervisor, United States Aluminum Co., 2210 Harvard Avenue, *Cleveland*.

STRATMAN, E. A. (J) assistant chief engineer, Vortox Mfg. Co., *Pomona, Cal.*

SUTTKUS, HENRY E. (A) foreman of engine department, Elco Boat Works, Bayonne, N. J.; (mail) *Fanwood, N. J.*

TOTTEN, CAPT. GERALD H. (S M) Quartermaster Corps; *Fort Sill, Okla.*

WEATHERLEY, VAUGHAN JOHN (J) engineer, Wright Aeronautical Corporation, *Paterson, N. J.;* (mail) 679 East 23rd Street.